Principal Component Analysis of Household Vulnerability to Flood Disaster in Makurdi Metropolis, Benue State, Nigeria

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ABSTRACT

Flood disasters are increasing becoming frequent and recurring in Nigerian urban areas with all its attendant destructive consequences. This study assessed household vulnerability to flood disaster in Makurdi metropolis, Benue State, Nigeria. The study employed both direct field measurement and 400 questionnaire for data collection on vulnerability factors and indicators. Principal Component Analysis was used to generate weights of vulnerability factors (Exposure, Adaptive Capacity and Sensitivity) and their corresponding indicators so as to avoid the uncertainty of equal weighting given the diversity of indicators used. The result indicates that Makurdi is generally vulnerable to flood disasters with a Composite Flood Vulnerability Index (CFVI) of *0.443*. In terms of individual vulnerability factors, the result revealed a high resilience index (adaptive capacity) of 6.230; high sensitivity or susceptibility index of 3.970 and relatively high exposure index of 1.817. The study therefore recommends that steps should be taken to relocate households living in close proximity to River Benue, especially those in flood-prone areas so as to reduce their exposure and sensitivity to flood disasters.

Keywords: Disaster, Flood, Index, Household, Vulnerability.

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INTRODUCTION

Globally, over the past few decades, flood disasters have become one of the challenging environmental problems threatening the security of society and impeding economic development in cities. The frequency and magnitude of occurrences is however connected with changes in land use patterns, population explosion, paving and water storage space, caused by demographic, economic, political, cultural mutations (Zening, Yanxia and Huiliang, 2019) and increasing frequency of heavy rainstorms. In Nigeria for instance, for cities that are situated at the river banks, flooding is a critical environmental problem or major hazard that is continuously affecting effective functioning of urban environment, especially in the areas of sustained infrastructure and services, which are germane for sustainable livelihood and social cohesion. It often arises as a result of the extension of urban areas unaccompanied by development of strong drainage systems, adequate planning and disaster management strategies. Indeed, flooding is one of the most devastating hazards that are likely to increase in many urban centres in Nigeria (Odufuwa, Adedeji, Oladesu and Bongwa, 2012).

In Makurdi town, studies have shown that floods of varying magnitudes have become a recurrent yearly event with its attendant consequences on households' livelihoods, infrastructure and social services, thereby leaving households vulnerable (Ali, 2006; Ocheri and Okele, 2012; Ali, 2018). The most devastating floods in recent time were the events of 2012, 2015 and 2017 that severely destroyed houses, businesses, infrastructure and even lives. In spite of the high frequency of floods and regardless of the large population living in low-lying areas susceptible to urban, flash and river floods with its devastating implications for lives and property, the challenge of addressing vulnerability and adaptation to floods has received little attention in Makurdi metropolis. Meanwhile, research on flood vulnerability is needed to provide the much needed information for policy making and appropriate intervention(s) in study area.

In assessing flood vulnerability, Principal Component Analysis (PCA), though a data reduction method provides a veritable analytical tool as it is useful in generating weights for vulnerability factors/indicators required for computing Flood Vulnerability Indices (FVI) (Akukweand Ogbodo, 2015). Developing vulnerability indices/ factors to determine the degree of exposure of residents to flood, as well as their susceptibility and resilience (adaptation) which by extension principally incorporates social, economic and physical aspects of vulnerability is fundamental to policy and intervention programme(s) on flood risk management as well as the development of innovative adaptation strategies.

From literature, while studies on flood in Makurdi have focused more on flood damages and impact, no study has clearly addressed the issue of vulnerability. For instance, Ali (2006) investigated flood damage in Makurdi town, Ologunorisa and Tersoo (2006) examined rainfall pattern and its implication on flood frequency in Makurdi town, Ocheri and Okele (2012) analysed the social impact and people's perception of flooding in Makurdi town. This therefore creates a research gap that underscores the need for this study. This study therefore seeks to assess household vulnerability in Makurdi metropolis using PCA tool with a view of developing flood vulnerability indices that will be useful for policy and planning especially in flood risk management in the study area.

MATERIALS AND METHODS

Study Area

The study area is Makurdi Town in Makurdi Local Government Area of Benue State (Figure 1). The town is located at the bank of River Benue in the plain of Benue trough of middle belt region of Nigeria. The area is found between latitude 7°43' 50" N and longitude 8°32' 10" E (Figure 1).

Makurdi has a mean elevation of 92 metres above sea level and the town covers an area of 16 km^2 and has a total landmass of 700 km^2 (Ali, 2018). Makurdi is bounded by Nassarawa State to the North and West, Guma Local Government Area in the North and East and on the South and West by Gwer East and Gwer West Local Governments (all of Benue State).

The general low relief coupled with the fact that town is located within a floodplain, sizeable

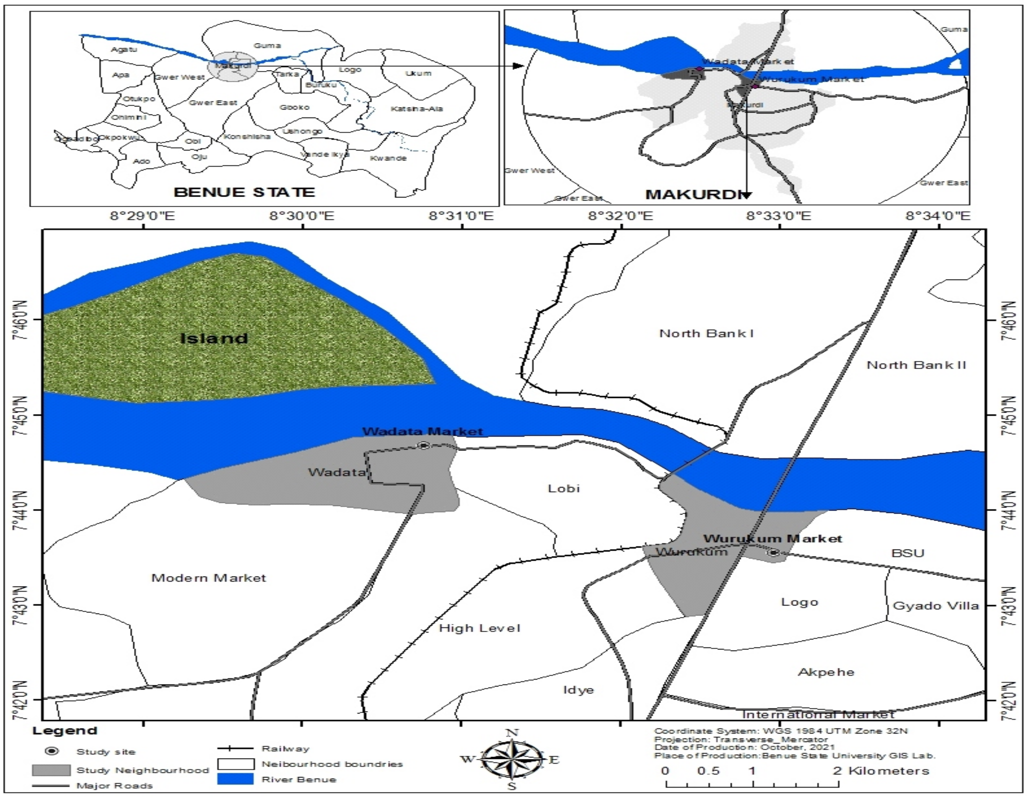

Figure 1: Makurdi Town showing Major neighbourhoods

Source: Benue State Ministry of Lands and Survey, 2017

portion of Makurdi experiences water logging and flooding each year especially during heavy rainstorms.

The area is entirely drained by the River Benue which divides it into north and south banks. Also, the study area has high drainage density though many of the rivers are seasonal. The presence of these rivers feeding the river Benue however, particularly during the peak rainfall period leads to increase in surface runoffs which subsequently bring about flooding especially in the months of August, September and sometime early October (Ali, 2006) . The streams which are either annual or perennial include, Kpege, Idye, Orudu, Adaka, Demekpe, Asase, Genebe, Kereke amongst others. These rivers drain Makurdi town and empty their water into the River Benue (Ocheri and Onah, 2014).

The area lies in the wet and dry savannah climate (Aw) and experiences a mean temperature of 28°c while mean monthly temperature values indicate that the coolest and hottest months are December (26°C) and March (31°C) respectively (Tyubee, 2008). Its relative humidity fluctuates with seasons, reaching its means monthly peak of about 92% in the rainy season, which begins in April, reaches its peak in August and decreases to end in October. The dry season on the other hand last for five (5) months (November March). The area has a mean annual rainfall total of 1190mm and annual rainfall total ranging between 775mm and 1792mm.

METHODS

The study employed both direct field measurements and questionnaire for data collection on vulnerability factors and indicators. For the purpose of questionnaire administration, a total of 400 sample size was determined using Yamane (1967) formula. The study employed multi-stage sampling procedure whereby different sampling techniques were used at various stages of sampling. Consequently, purposive, stratified and systematic sampling techniques were used in view of the nature of the study, covering a number of neighbourhoods and different vulnerability indicators. The first stage involved the selection of study neighbourhoods. In the stage, stratified sampling method was used together with purposive sampling technique in the identification and selection of neighbourhoods. To this end, study areas such as Wurukum, Wadata, North Bank I and II were purposively selected to constitute different strata. The selection was based on nearness to water body - in this case, River Benue and neighbourhoods with history of frequent flood occurrences. The second stage involved the sampling of 400 households from the selected neighbourhoods that constituted the study units. Here, systematic and purposive sampling methods were applied in sampling of four hundred (400) households across the six (6) selected neighbourhoods in the study area.

The third stage featured the selection of actual respondents. Here, respondents were selected based on the criteria of being household members of the neighbourhoods and on their ability to respond to questions put to them appropriately. In doing this priority was given to the heads of the households in responding to questions as contained in the questionnaire, however, where the household head was indisposed, the most elderly with the ability to respond to question was selected.

Computation of Flood Vulnerability index (FVI) Using PCA

The following steps were followed in determining FVI using PCA.

Step I: In computing FVI, the first step was to quantify the various vulnerability indices as specified on Table 1.

Step II: The weights of these indicators were determined using PCA and the component loading of the first component was used. This was consistent with the method used by Akukwe and Ogbodo (2015). In their study, PCA was run on the variables, and the weights were attached the indicators using the first principal component scores of the indicators. The reason for assigning the weights determined by PCA to indicators was to avoid the uncertainty of equal weighting given the diversity of indicators used (Akukwe and Ogbodo, 2015; and Deressa, Hassan and Ringler, 2008). Thus, for the determination of the vulnerability indices, the selected indicators of sensitivity and exposure were negatively associated with their first principal component because it was assumed that areas with higher frequencies of flooding were subjected to higher sensitivity due to the adverse effects of flooding as well as being more exposed. On the other hand, adaptive capacity was positively associated with the first principal components because it is assumed that people with higher adaptive capacity were less sensitive to damages caused by flooding, holding exposure level constant. Thus, higher values of the vulnerability indices show less vulnerability and vice *versa* (Akukwe and Ogbodo, 2015; Deressa et al., 2008; and Madu, 2011).

Step III: Consequently, vulnerability to flood was computed according to Deressa et al., (2008); and Akukwe and Ogbodo, (2015) as follow: **FVI** = /Adaptive Capacity/ - / Sensitivity + Exposure/ (1)

Akukwe and Ogbodo, (2015) explained the

adoption of this formula, maintaining that this equation was adopted because flooding is one of the consequences of climate.

Equation (1) was expanded as follows: FVI = $(wAC_1 + wAC_2 + wAC_3 + \dots wAC_n)$ $(wS_1 + wS_2 + wS_3 + \dots wS_n)$ + $(wE_1 + wE_2 + wE_3 + \dots wE_n)$ (2)

Where *FVI* is vulnerability index, *w* are weights of first components scores, $AC_1 \dots AC_n$ are adaptive capacity variables, $S_1 \dots S_n$ are sensitivity Variables, and $E_1 \dots E_n$ are the exposure variables.

Note

AC = Adaptive Capacity; S = Sensitivity; and E = Exposure

RESULTS AND DISCUSSION

The result PCA is presented in Table 2, while that of Computed Weight of Flood Vulnerability Indicatorsis shown on Table 3._The result of the PCA of the data set on vulnerability indicators extracted four components with Eigenvalues greater than 1 (Table 2). The result revealed that these four components accounted for 90.953% of the total variance explanation in the data set, which implies that the percentage variance explanation by these components is very high.

The first principal component explained most of the variation in the flood vulnerability indicators with an eigenvalue of 18.692 and the percentage variance explanation of 69.23%. The result generally showed a very high factor loadings on the flood vulnerability variables measured except for frequency of flood occurrence. However, the first five factor loadings were on adaptive capacity indicators, hence the first component is named Adaptive Capacity *Component,* which is an indication that the study has high resilience capacity to cope with flood disaster which suggests a low level of vulnerability.

The second component with an eigenvalue of 3.145 accounted for 11.68% explanation of the variation in flood vulnerability indicators. The component is negatively highly loaded on assistance to flood victims that is the organization providing assistance, therefore the component is named *Flood Intervention Bodies Component*. The negative loading could suggest lack of coordination among the organization providing assistance to flood victims. It could also suggest inadequate assistance to the flood victim which could increase their vulnerability level.

The third component with an eigenvalue of 1.640 accounted for 6.075% explanation in the variation in the flood vulnerability indicator. It is highly loaded on frequency of flood and past flood experiences which are all sensitivity indicators therefore the component is named *sensitivity indicators Component.* However, the loadings are below 0.5 thresholds which indicate a relatively high sensitivity to flood implying a higher vulnerability tendency.

The fourth component with an eigenvalue of 1.080 explained the least (4.000%). The higher loading here is of past flood experience, hence, the component could be named *Flood Experience Component.* This sensitivity indicator could equally mean high sensitivity to flood event in the study area.

The first principal component, which explained the majority of the variation in the data set as shown in table 2 was taken (that is, it served as the weight) and used in the computation of the vulnerability indices for the study area.

Results of the Flooding Vulnerability Indices in Makurdi

The result of the composite vulnerability index for Makurdi is presented in Table 3. Using equation (1), the vulnerability indices for Makurdi was Computed with values in tables 3. The component scores from the first component were used to construct vulnerability index for the areas under study.

Table 1: Vulnerability, Units of Measurement, and Their Relationship Vulnerability

Determinant of vulnerability	Vulnerability indicator	Description of each indicator	Units of Measurement	Relationship between indicator and Vulnerability
Adaptive or Resilience Capacity	Wealth	Average Annual income Receipt of assistance/relief	% of total population who earned more than N500,000.00 per annum % of population who received assistance	The higher the % of total population more than N500,000.00 per annum, who receive, who are educated, who are employed outside primary production sector like farming, the lesser the vulnerability.
	Literacy rate	Educational qualification	% population who are educated	
	Employment status	Occupation	% of population that are less vulnerable	
Sensitivity or Susceptibility	Flood characteristics	Length of stay - The number of years of residence	% of population that have stayed longer than 10 years	The higher the frequency, the more the vulnerability. The higher the numbers the higher the vulnerability The higher the extent of coverage/magnitude, the higher the vulnerability
		Frequency of Flood occurrence	Frequency of Flood occurrence in a year	
		Period of flood occurrence in a year	Number of months with flood in a year	
		Severity	Extent of coverage	
	Flood perception	Pre-flood awareness	% of population with pre-flood awareness	
	Flood experience	Past flood experience	% population who had experience flood	
Exposure	Proximity to water body	Average Distance from River	The average distance to flood prone areas	The shorter the average distance to water body, the higher the vulnerability The longer it takes for flood to recede the higher the vulnerability
	Flood duration	Number of days it takes for flood to recede	Number of days with flood water	

Source: Adapted from Akukwe and Ogbodo,(2015) with modification to suit the variable of interest to this study.

Generally, the result indicates that Makurdi is highly vulnerable, with vulnerability index of *0.443*.

In terms of total weight of individual vulnerability indicators, the result on table 3 revealed that Makurdi has a relatively higher resilience index of 6.230. Adaptive capacity has an inverse relationship with vulnerability, which means that the higher the adaptive capacity, the lower the vulnerability. This is so because, adaptive capacity has to do with the economic and social capital or resource base of individuals and communities of flood affected areas. This follows that the higher the socioeconomic capital, the higher the resilience of individuals /household/ communities during flood events. To this end, the result on table 3 shows that Makurdi residents have considerable cumulative socioeconomic

Table 2: Component Matrix (rotated)

Variables	Component 1	2	3	4
Educational qualification	*.981*	.001	-.023	.002
Occupation	*.961*	.174	.004	-.010
Ethnic group	*.955*	.149	-.022	-.129
Nature of business	*.950*	.107	-.225	-.011
Coping strategy	*.930*	-.199	-.149	.002
Age	.930	.001	.128	.110
Annual income	.924	-.228	.102	.022
Days to recede (duration)	.924	-.220	-.321	.001
Distance from river mouth	.920	.110	.167	-.151
How long do you relocate	.896	.012	-.342	-.330
Extent of coverage	.893	.345	-.204	-.020
Annual flood loss	.887	-.165	-.271	.147
If yes how long	.875	-.416	.0320	.001
Length of stay	.851	-.339	.150	.107
Render you homeless	.826	-.005	-.436	.033
Other source of income	.802	-.395	.232	-.251
Why not relocated	.786	*.559*	.143	.022
Marital status	.783	.010	*.434*	-.169
Sex	.782	.473	-.150	.320
Keep you from business	.781	.478	-.142	.005
Assistant from anybody	.761	*-.555*	-.002	-.116
Pre-flood Awareness	.744	-.578	.004	-.129
Nature of assistance	.741	.386	.380	.260
Specify who help	.732	*-.582*	.181	.123
Period of flood	.726	.495	.278	.130
Frequency of flood	.483	.420	*.446*	-.394
Past flood experience	.273	-.226	*.424*	*.773*
Total Eigenvalues	18.692	3.145	1.640	1.080
% of Variance	69.230	11.648	6.075	4.000
Cumulative %	69.230	80.878	86.953	90.953

Extraction Method: Principal Component Analysis.
a. 4 components extracted.

capital to mitigate or cope, however, this is still not at the optimal level of 1.00 or 100%. Makurdi residents have diverse sources of income, thereby making them less vulnerable.

However in terms of sensitivity or susceptibility, the result shows that Makurdi area is more susceptible to flooding with the index of 3.970. Generally, the higher the susceptibility index, the higher the vulnerability. This implies that Makurdi is relatively vulnerable as far as sensitivity index is concerned. However, the effect of Makurdi's high susceptibility was reduced by its higher adaptive capacity index, making Makurdi less vulnerable when the two indices are considered, since Makurdi households possess substantial socioeconomic capital to deal with flood disaster in

Table 3: Computed Weight of Flood Vulnerability Indicators

Variable/Vulnerability Factor/Indicator Adaptive Capacity or Resilience	Weight
Education	0.981
Occupation	0.961
Average annual Income	0.924
Coping Strategies	0.930
Assistance	0.961
Nature of assistance	0.741
Source(s) of assistance	0.732
Total Weight	**6.23**
Sensitivity or susceptibility Indicators	
Length of stay	0.851
Period of flood occurrence in a year	0.726
Frequency of Flood occurrence	0.483
Extent of coverage	0.893
Pre-flood awareness	0.744
Past flood experience	0.273
Total Weight	**3.97**
Exposure Indicators	
Average Distance from River	0.893
Flood duration	0.924
Total Weight	**1.817**

Source: Computed from First Principal Component Scores

spite of the high susceptibility.

Similarly, the result on the level of exposure to flooding as shown by the computed index on table 3 indicates that Makurdi is highly exposed to flood disasters with the exposure index of 1.817. Just like sensitivity indices, the higher the exposure of a place to flood, the higher the vulnerability. This implies that the percentage of those leaving in close proximity to the river in Makurdi and the incidences of flash floods is high. Also, the flood duration in terms of the numbers of days flood waters take to recede tend to be high in Makurdi.

Again, the effect of high exposure of Makurdi area was overridden by the higher adaptive capacity of this area thereby keeping the overall flood vulnerability in this place positive (*+0.443)* even though it is still relatively low. Overall, the observed positive vulnerability index of Makurdi could be connected to the fact that urban areas tend to enjoy high income, better educational facilities and social support network than rural areas with inadequate social amenities and low income generated largely from engaging in primary production. From Table 3, Composite Flood Vulnerability Index (CFVI) is computed as follows: Flood Vulnerability Index, CFVI = 6.230 3.970 + 1.817 = + *0.443*

CONCLUSION

The study concludes that Makurdi metropolis is generally vulnerable to flood disasters due to high level of exposure and susceptibility even though it has relatively high adaptive capacity. The study therefore recommends that steps should be taken to relocate household living in close proximity to River Benue, especially those in flood-prone areas so as to reduce their exposure and sensitivity to floods. Pre-flood awareness and early warning system should be strengthened so to reduce households' susceptibility to flood disaster in the study areas.

REFERENCES

Akukwe T. I., and Ogbodo, C. (2015) Spatial Analysis of Vulnerability to Flood in Port Harcourt Metropolis, Nigeria. Sage Open. DOI: 10, 1177/2158244015575558

Ali, P. I. O. (2018). Assessment of Household Vulnerability and Adaptation to Flooding in Makurdi Town, Benue State, Nigeria Unpulished Ph.D thesis, Department of Geography, Benue State University, Makurdi, Nigeria.

Ali, P.I. (2006) Flood damage assessment in Makurdi town, M.Sc Project, Department of Geography, Benue State University, Makurdi, Unpublished.

Ocheri, M. and Okele,E. (2012) Social impacts and people's perception of flooding In Makurdi town, Nigeria, in: Martins, O., Idowu, O. A., Mbajiorgu, C.C., Jimoh, O. D. and

Oluwasanya, G. O. (eds), Hydrology for Disaster Management, special publication of the Nigerian Association of Hydrological Sciences, 2012, 97-105.

Ocheri, M. I. and Onah, M. A.(2014) Effect of climate change and land use activities on rural water sources in Benue State:in Conference proceedings of 2014 international conference on climate change and sustainable economic development of the Nigerian Meteorological Society. Seron Press, Makurdi

Odufuwa, B.O., Adedeji O. H., Oladesu, J. O. and Bongwa, A.(2012). Floods of Fury in Nigerian Cities. Journal of Sustainable Development, 5,(7); 2012 ISSN 1913-9063 E-ISSN 1913-9071

Ologunorisa, T.E. and Tersoo, T (2006). The changing rainfall pattern and it implication for flood frequency in Makurdi, Northern Nigeria. Journal of Applied and Environmental Management, 10 (3).

Zening, W., Yanxia, S. and Huiliang, W. (2019). Assessing Urban Areas' Vulnerability to Flood Disaster Based on Text Data: A Case Study in Zhengzhou City. Sustainability 2019, 11, 4548; doi:10.3390/su11174548 www.mdpi.com/journal/sustainability.