EVALUATION OF FLOOD INDICES IN SELECTED AREAS OF PORT HARCOURT METROPOLIS USING ANALYTIC HIERARCHY PROCESS (AHP) MODEL

Ajoku, Chrys U.*[1], Ugbebor, John N.[2]
[1]Department of Civil and Environmental Engineering, University of Port Harcourt
[2]Department of Civil and Environmental Engineering, University of Port Harcourt

**Corresponding: john.ugbebor@uniport.edu.ng*

Abstract -The increasing spread of seasonal and flash flood in residential and commercial areas of Port Harcourt in Rivers State of Nigeria has become issue of great concern. The study therefore evaluated the causes of flooding in selected areas of Port Harcourt metropolis using Analytic Hierarchy Process (AHP) decision-making approach. GPS was deployed for measurements of bearing and elevations of the study areas of Nkpolu, Eneka and Choba communities which showed latitudes between4°50'N and 4°53'Nand longitudes between6°55'E and 7°01'E; and elevations of 49ft, 67ft and 55ft respectively. The study identified four (4) indices, ranked in a Pairwise Comparison Chart using the AHP model. The results indicated that elevation, slope, natural drainage and availability of manmade drains ranked 33%,21.3%,14.06% and 10.05% respectively and these were found to be the most influential indices that cause flooding in Port Harcourt metropolis. Other indices which constitute minor causes of flood were Population, Land-use, flow accumulation, average monthly rainfall intensity, and the Soil composition with percentage weighted indices of 6.28%, 6.14%, 3.60%, 3.54%, and 2.04% respectively. The Consistency Ratio of 0.052 from the AHP indicates a high degree of accuracy, and reliability. The researchers recommended suitable channel network and drainage sizes linked to flowing water body as a panacea to flood problems in the study area.

Keywords: Flash flood, Analytic Hierarchy Process (AHP) model, flood indices, decision-making, drainage

1. INTRODUCTION

The increasing spread of areas affected by seasonal and flash flood in coastal areas in Nigeria and the resulting effects of flooding to lives and properties is of a great concern. Seasonal and flash flooding is the bane of coastal areas partly due to their excessive rainfall round the year and partly due to the low-lying topography of such cities or states. Many cities of coastal states have recorded several losses of lives and destruction of properties. (Olayinka and Irivbogbe, 2017).

According to Ishaya (2009), Nigeria has lost properties and lives worth millions of Naira directly from flooding every year. A very remarkable case is that of the coastal areas of Bayelsa and Rivers States in October of the year, 2012 where 64.42sq km total land area were affected by the flood (Wizor, *et al.*, 2014) causing displacements of residents, destruction of properties and death in towering toll; according to the Office of the Coordination of Humanitarian Affairs in United Nations (OCHA), 2012.

Therefore, solving seasonal flood problems in areas identified to be prone to flooding especially in Port Harcourt and its environs in Rivers State, the study deployed decision-making model such as Analytic Hierarchy Process (AHP) to identify the indices that contribute to this most complicated of natural perils that happens over a spatial space in a considerably short time.

The occurrence of floods in some areas have scuttled commercial activities and led to destruction of properties because the residents are not aware of the flood susceptibility of such areas before occupying them.

While in some parts of Nigeria, many researchers have used Remote Sensing and Geospatial Information System (GIS) to map areas that may be vulnerable to flood, with its attendant complexities, some other areas are yet to be studied. For instance, Ishaya et al., (2009) mapped areas vulnerable to flood in Gwagwalada Urban area in Abuja FCT. Olayinka et al., (2017) developed flood maps for Eti-Osa, Festac and Lagos Island in Lagos State.

The aim of the study, therefore, is to determine flood vulnerability indices as an approach to solving flood problems in selected areas of Port Harcourt and environs. This was achieved through identification of indicators that have role in flooding of study areas.Primary and secondary data acquisition includinguse of questionnaire, and computed weights for these indicators using the Pairwise Comparison approach. Results were presented in charts for proper analysis and interpretation.

1.1 STUDY AREA

The study areas were major flash areas identified recently to be vulnerable to flood. These include Nkpolu-East West Road-Airport Road-Rumuagholu enclave, Eneka-Elimgbu (Igwuruta)-East West Road-Rumuodara enclave and Choba-Rumualogu Road stretch, all in Obio/Akpor Local Government Area of Rivers State. The study areas are within the Port Harcourt metropolis comprising two (2) Local Government Areas - Port Harcourt (PHALGA) and Obio-Akpor (OBALGA). The areas are between latitude 7°04'E and 6°55'E with longitude 4°50'N and 4°53'N respectively. These areas have recorded flood occurrence in the recent past. The detailed map of the study area is shown in Figure 1:

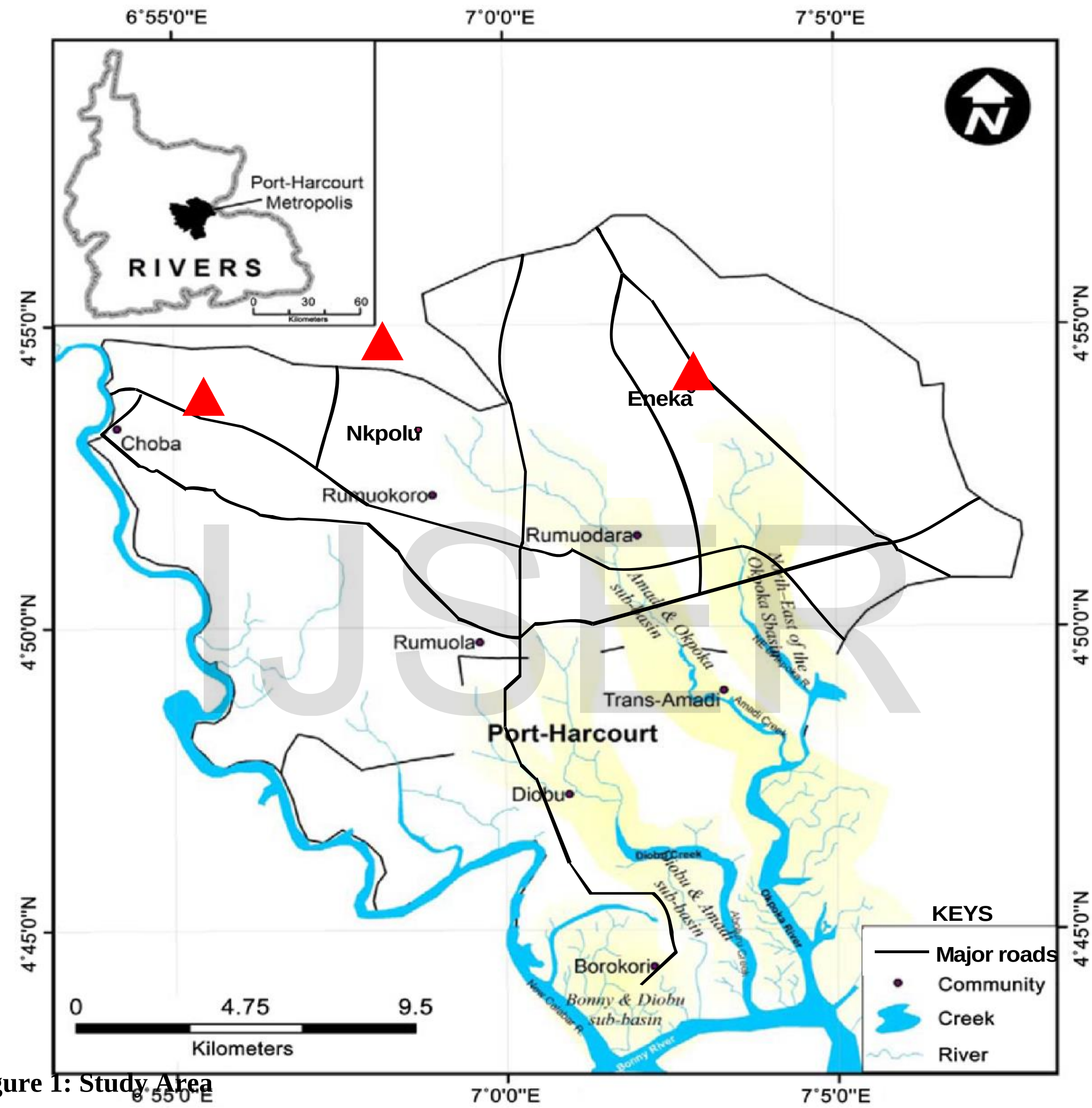

Figure 1: Study Area

2. MATERIALS AND METHODS

Land-use, Soil composition, Population, Natural drainage, Slope, Elevation, Availability of manmade drains, Average monthly rainfall intensity and Flow accumulation were studied indices. To authenticate this qualitative study, research questions were developed in order to carry out a questionnaire-based research. The research questions are:

i. What is the importance of each of these indices in influencing flooding in places like Nkpolu, Eneka or Choba in Port Harcourt as compared to the other?

2.1 RESEARCH QUESTIONNAIRE DEVELOPMENT

Population size

The study adopted the representative sampling technique which produced a quantitative data from a large survey in a study area as shown in Tables1a and 1b:

Table 1a: Obio/Akpor Census (1991 & 2006) with Estimated Population (2016 & 2018)

Name	Status	Census Population in 1991 (NBS and NPC)	Census Population in 2006 (NBS and NPC)	Estimated Population in 2016 (using Growth Rate +3.46%)	Estimated Population in 2018 (using Growth Rate +3.46%)
Obio/Akpor	LGA	263,017	462,350	649,600	695,330

Source: National Bureau for Statistics and National Population Commission (Retrieved 2019)
Population Density (PD) for Obio/Akpor LGA: 2498/sq.km
Growth rate: +3.46% per year (since 2006)

The study used a representative sampling method to reach persons in a particular age group and of a particular educational exposure. The Census Data obtained was complemented with an analysis from City Population website application and Table 1b showed the simplified output:

Table 1b: Obio/Akpor Census analyzed in Age Groups (2006-2018)

	Study Area Age Distribution in % (City Population website) (Obio/Akpor LGA)	Age Distribution 2006 (Obio/Akpor LGA)	Age Distribution in 2016 (Obio/Akpor LGA)	Age Distribution in 2018 (Obio/Akpor LGA)
20 - 29yrs	25.77%	119,133	167381	179165
30 - 39yrs	16.19%	74,851	105165	112569
40 - 49yrs	8.36%	38,675	54338	58163
50 - 59yrs	3.79%	17,515	24609	26341
60 - 69yrs	1.53%	7,082	9950	10651
Total				**386888**

Source: City Population: https://www.citypopulation.de (Retrieved in June 2019)

Now, the study areas are communities in Obio/Akpor LGA with land mass areas estimated from Google Earth (2018) to be 2.71sqKm (Nkpolu), 8.13sqKm (Eneka) and 2.25sqKm (Choba) respectively. This gives rise to their population data being computed using the Population Density (PD) and Growth Rate (as given by the NBS and NPC report). Tables 2, 3 and 4 showed the computed population data for Nkpolu, Eneka and Choba.

The Table 2b showed the analyses of Nkpolu population estimated in the different age groups.

Table 2a: Nkpolu Estimated Population (2006-2018) using PD, Area & Growth Rate

Name	Status	Census Population in 1991 (NBS and NPC)	Estimated Population for Study Area in 2006 (PD x Area)	Estimated Population for Study Area in 2016 (using Growth Rate +3.46%)	Estimated Population for Study Area in 2018 (using Growth Rate +3.46%)
Nkpolu	Study Area	N/A	6,745	9,477	10,144

Table 2b: Nkpolu Estimated Population analyzed in Age Groups (2006-2018)

	Study Area Age Distribution in % (City Population website)	Study Area Age Distribution in 2006 (Nkpolu Estimated)	Study Area Age Distribution in 2016 (Nkpolu Estimated)	Study Area Age Distribution in 2018 (Nkpolu Estimated)
20 - 29yrs	25.77%	1738	2442	2614
30 - 39yrs	16.19%	1092	1534	1642
40 - 49yrs	8.36%	564	792	848
50 - 59yrs	3.79%	256	359	384
60 - 69yrs	1.53%	103	145	155
Total				**5644**

In Table 3a, the population data for Eneka are computed and Table 3b showed the analyses of Nkpolu population estimates in the different age groups

Table 3a: Eneka Estimated Population (2006-2018) using PD, Area & Growth Rate

Name	Status	Census Population in 1991 (NBS and NPC)	Estimated Population for Study Area in 2006 (PD x Area)	Estimated Population for Study Area in 2016 (using Growth Rate +3.46%)	Estimated Population for Study Area in 2018 (using Growth Rate +3.46%)
Eneka	Study Area	N/A	20,309	28,537	30,546

Table 3b: Eneka Estimated Population analyzed in Age Groups (2006-2018)

	Study Area Age Distribution in % (City Population website)	Study Area Age Distribution in 2006 (Eneka Estimated)	Study Area Age Distribution in 2016 (Eneka Estimated)	Study Area Age Distribution in 2018 (Eneka Estimated)
20 - 29yrs	25.77%	5235	7356	7874
30 - 39yrs	16.19%	3288	4621	4946
40 - 49yrs	8.36%	1698	2386	2554
50 - 59yrs	3.79%	770	1082	1158
60 - 69yrs	1.53%	311	437	467
Total				**16,999**

The population data for Choba study area as shown in Table 4a:

Table 4a: Choba Estimated Population (2006-2018) using PD, Area & Growth Rate

Name	Status	Census Population in 1991 (NBS and NPC)	Estimated Population for Study Area in 2006 (PD x Area)	Estimated Population for Study Area in 2016 (using Growth Rate +3.46%)	Estimated Population for Study Area in 2018 (using Growth Rate +3.46%)
Choba	Study Area	N/A	5,621	7,898	8,454

Table 4b showed the analyses of Nkpolu population estimates in the different age groups.

Table 4b: Choba Estimated Population (2006-2018) using PD, Area & Growth Rate

ISSN 2229-5518

	Study Area Age Distribution in % (City Population website)	Study Area Age Distribution in 2006 (Choba Estimated)	Study Area Age Distribution in 2016 (Choba Estimated)	Study Area Age Distribution in 2018 (Choba Estimated)
20 - 29yrs	25.77%	1449	2035	2179
30 - 39yrs	16.19%	910	1279	1369
40 - 49yrs	8.36%	470	660	708
50 - 59yrs	3.79%	213	299	320
60 - 69yrs	1.53%	86	121	129
Total				**4705**

Determination of Sampling size using Taro Yamane's Formula
The sampling size related to the study population sampling buttressed by Denscombe (2010). The sample size was obtained using the statistical formula by Taro Yamane (1967) and applied to a similar study by Elenwo (2015). The formula is thus:

$$n = \frac{N}{1 + N(e^2)} \quad 1$$

n = Sample size
N = Population size under study
e = Margin error (which could be 0.5%, 1%, 5%, or 10%) showing level of significance.
A level of significance of 0.5% meant that the result from the questionnaire survey is about 99.5% accurate and a level of significance of 10% meant that the survey conducted is about 90% accurate.
The sample size (*n*) for Nkpolu, Eneka and Choba were 98.3, 99.4 and 97.9 respectively. This is approximated as 100 samples for each location. A total of 360 copies of Questionnaire were distributed, 120 per study area.

The indices compared in the Pairwise Comparison Chart (PCC)are assigned their equivalent numbers as shown in Table 5

Table 5: The Basic Scale of Absolute Numbers and their Intensity of Importance

Intensity	**Definition**	**Definition Explanation**
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance Moderate importance	Experience and Judgement slightly favour one activity over another
3 4	Moderate plus importance Strong importance	Experience and judgement strongly favour one activity over another
5 6	Strong plus importance Very strong/demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
7 8 and 9	Very, very strong importance Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals (1/2, 1/3, 1/4 etc.)	Inverse importance	This relates to the inverse case of the real definition.

2.2 DETERMINATION OF PERCENTAGE WEIGHT OF THE FLOOD INDICATORS
The Analytic Hierarchy Process (AHP) model was used to determine which of the indices identified has great influence on the flooding incidents as recorded or predicted. It totally incorporates the Pairwise Comparison Chart (PCC) which is a tool that has been useful in decision making in environmental impact assessment.

Table 6: Pairwise Comparison Chart (PCC) of the Nine (9) Identified Indices to Determining Flooding.

		J								
		L	SC	P	ND	S	E	AMD	ARI	FA
I	**Land-use (L)**	1	3	1/2	1/3	1/4	1/6	1/2	4	3
	Soil composition (SC)	1/3	1	1/3	1/6	1/9	1/8	1/7	1/3	1/2
	Population (P)	2	3	1	1/3	1/7	1/5	1/3	4	2
	Natural drainage (ND)	3	6	3	1	1/2	1/3	2	4	3
	Slope (S)	4	9	7	2	1	1/2	3	6	2
	Elevation (E)	6	8	5	3	2	1	4	9	9
	Availability of manmade drains (AMD)	2	7	3	1/5	1/3	1/4	1	2	3
	Average rainfall intensity (ARI)	1/4	3	1/4	¼	1/6	1/9	1/2	1	2
	Flow accumulation (FA)	1/3	2	1/2	1/3	1/2	1/9	1/3	1/2	1

Thissa me process was applied in attaching the intensity of importance value to each comparison and adjustments were made until an acceptable consistency ratio was obtained.The chart translates into Table 7 (with the values in decimals).

Table 7: Pairwise Comparison Chart (PCC) in Decimals.

		J								
		L	SC	P	ND	S	E	AMD	ARI	FA
I	**Land-use (L)**	1.00	3.00	0.50	0.33	0.25	0.17	0.50	4.00	3.00
	Soil composition (SC)	0.33	1.00	0.33	0.17	0.11	0.13	0.14	0.33	0.50
	Population (P)	2.00	3.00	1.00	0.33	0.14	0.20	0.33	4.00	2.00
	Natural drainage (ND)	3.00	6.00	3.00	1.00	0.50	0.33	2.00	4.00	3.00
	Slope (S)	4.00	9.00	7.00	2.00	1.00	0.50	3.00	6.00	2.00
	Elevation (E)	6.00	8.00	5.00	3.00	2.00	1.00	4.00	9.00	9.00
	Availability of manmade drains (AMD)	2.00	7.00	3.00	0.50	0.33	0.25	1.00	2.00	3.00
	Average rainfall intensity (ARI)	0.25	3.00	0.25	0.25	0.17	0.11	0.50	1.00	2.00
	Flow accumulation (FA)	0.33	2.00	0.50	0.33	0.50	0.11	0.33	0.50	1.00
	∑ (SUM)									

The values on the row are then multiplied together and the nth root of their product was determined. Where n, in this case, is 9. The tabulated output was shown in Table 8.

Table 9: Evaluating the 9th Root of the PCC Matrix

		J										
		L	SC	P	ND	S	E	AMD	ARI	FA	MULT	9th Root of Product
I	**Land-use (L)**	1.00	3.00	0.50	0.33	0.25	0.17	0.50	4.00	3.00	0.13	0.806
	Soil composition (SC)	0.33	1.00	0.33	0.17	0.11	0.13	0.14	0.33	0.50	0.00001	0.264
	Population (P)	2.00	3.00	1.00	0.33	0.14	0.20	0.33	4.00	2.00	0.15	0.811
	Natural drainage (ND)	3.00	6.00	3.00	1.00	0.50	0.33	2.00	4.00	3.00	216	1.817
	Slope (S)	4.00	9.00	7.00	2.00	1.00	0.50	3.00	6.00	2.00	9072	2.753
	Elevation (E)	6.00	8.00	5.00	3.00	2.00	1.00	4.00	9.00	9.00	466560	4.265
	Availability of manmade drains (AMD)	2.00	7.00	3.00	0.50	0.33	0.25	1.00	2.00	3.00	10.5	1.299
	Average rainfall intensity (ARI)	0.25	3.00	0.25	0.25	0.17	0.11	0.50	1.00	2.00	0.0009	0.457
	Flow accumulation (FA)	0.33	2.00	0.50	0.33	0.50	0.11	0.33	0.50	1.00	0.0010	0.466
	∑ (SUM)											**12.92**

Table 9 showed the values of the 9th root and the summation was given to be 12.92. Hence, in obtaining the criteria weights of each indices, the nth root obtained has to be normalized. Table 10 showed the criteria weight obtained from normalizing the 9th root.

Table 10: Normalizing the 9th Root to Obtain the Criteria Weight of Each Index.

Indices	9th Root of the Product	Criteria Weight

Land-use	0.805564	0.061413
Soil composition	0.2635	0.020388
Population	0.811362	0.062779
Natural drainage	1.817121	0.1406
Slope	2.752611	0.212984
Elevation	4.264603	0.329975
Availability of manmade drains	1.29857	0.100477
Average rainfall intensity	0.456918	0.035359
Flow accumulation	0.465626	0.036028
∑ (SUM)	**12.92401**	**1.000000**

The consistency ratio was used to check how consistent and dependable our pairwise comparison was. The results were tabulated in Tables 11 and 12.

Table 11: Multiplying Criteria Weight by the Summation of PC Values (SUM PV)

		J										
		L	**SC**	**P**	**ND**	**S**	**E**	**AMD**	**ARI**	**FA**	**MULT**	**9th Root of Product**
	Land-use (L)	1.00	3.00	0.50	0.33	0.25	0.17	0.50	4.00	3.00	0.13	0.806
	Soil composition (SC)	0.33	1.00	0.33	0.17	0.11	0.13	0.14	0.33	0.50	0.00001	0.264
	Population (P)	2.00	3.00	1.00	0.33	0.14	0.20	0.33	4.00	2.00	0.15	0.811
I	**Natural drainage (ND)**	3.00	6.00	3.00	1.00	0.50	0.33	2.00	4.00	3.00	216	1.817
	Slope (S)	4.00	9.00	7.00	2.00	1.00	0.50	3.00	6.00	2.00	9072	2.753
	Elevation (E)	6.00	8.00	5.00	3.00	2.00	1.00	4.00	9.00	9.00	466560	4.265
	Availability of manmade drains (AMD)	2.00	7.00	3.00	0.50	0.33	0.25	1.00	2.00	3.00	10.5	1.299
	Average rainfall intensity (ARI)	0.25	3.00	0.25	0.25	0.17	0.11	0.50	1.00	2.00	0.0009	0.457
	Flow accumulation (FA)	0.33	2.00	0.50	0.33	0.50	0.11	0.33	0.50	1.00	0.0010	0.466
	∑ (SUM)	**18.92**	**42.0**	**20.58**	**7.92**	**5.00**	**2.80**	**11.81**	**30.83**	**25.50**		**12.92**

Table 12: Summation of PC Values

Indices	Criteria Weight (CW)	SUM PV	SUM PV x CW
Land-use	0.061413	18.917	1.161727
Soil composition	0.020388	42.000	0.856313
Population	0.062779	20.583	1.292209
Natural drainage	0.1406	7.917	1.113086
Slope	0.212984	5.004	1.065766
Elevation	0.329975	2.797	0.923014
Availability of manmade drains	0.100477	11.810	1.18659
Average rainfall intensity	0.035359	30.833	1.090089
Flow accumulation	0.036028	25.500	0.918713
∑ (SUM)		**X**	**9.607507**

The Consistency Index (CI), which is required for the direct determination of the consistency ratio, was calculated using the Equation 3.2(Saaty, 1990 and Kunz, 2010):

$$CI = \frac{(X-n)}{n-1}$$

(Where n, number of identified indices = 9 and value of X = 9.607507)

$$CI = \frac{(9.607507-9)}{9-1}$$

$$CI = \frac{0.607507}{8} = 0.075938$$

The value of CI was 0.076. Consistency Ratio (CR) was calculated using Equation 3.3, where Random Index (RI) is 1.45 (Saaty, 1990; Kunz, 2010; Olayinka and Irivbogbe, 2017).

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.075938}{1.45}$$

$CR = 0.052371$

The consistency ratio (CR) obtained was 0.052, and this value is less than 0.1. It showed that pairwise comparisons conducted and criteria weights obtained are consistent, dependable and accurate respectively, for the decision-making process of identifying indices that determines the flood vulnerability of these selected areas in Port Harcourt. Converting the weights to percentage values, we have the percentage influence of each index; presented in Table 13 and 14.

Table 13: Evaluating the Percentage Influence of Each Index

Indices	Criteria Weight	Percentage Influence (%)
Land-use	0.061413	6.14
Soil composition	0.020388	2.04
Population	0.062779	6.28
Natural drainage	0.1406	14.06
Slope	0.212984	21.30
Elevation	0.329975	33.00
Availability of manmade drains	0.100477	10.05
Average rainfall intensity	0.035359	3.54
Flow accumulation	0.036028	3.60
∑ (SUM)	**1.000000**	**100**

Table 14: Percentage Influence as attached to their Indices in the Study

Indices	Percentage Influence (%)
Land-use	6
Soil composition	2
Population	6
Natural drainage	14
Slope	21
Elevation	33
Availability of manmade drains	10
Average rainfall intensity	4
Flow accumulation	4
∑ (SUM)	**100**

3. RESULTS AND DISCUSSION

Population Distribution of Study Area

The population size that made up each study area was computed in detail in Table 1b. Hence, the age distribution and percentage of those eligible to participate in the survey are shown with Figure 2

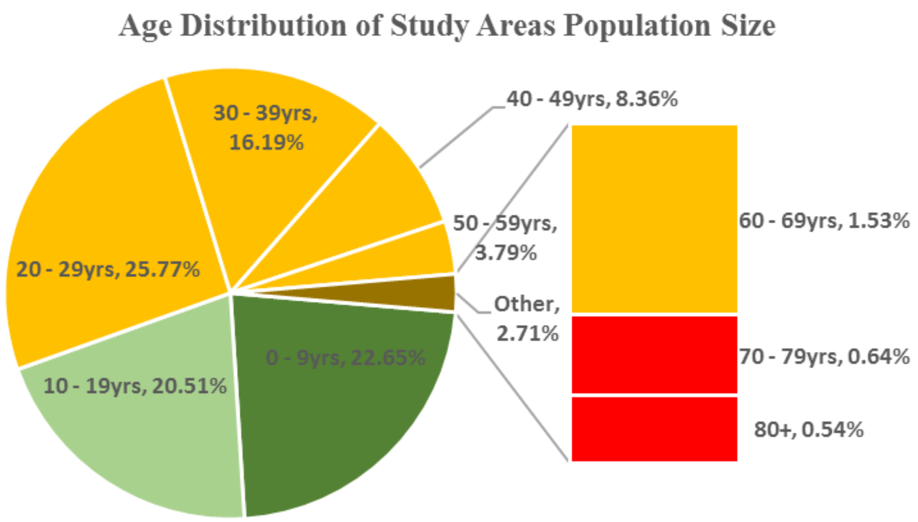

Figure2: Age Distribution of Study Area showing Percentage of the entire Population eligible for Survey.

Eligibility for the questionnaire survey was based on level of exposure which is graduate, post graduate or advanced opinion leaders. The sectors in green shades showed the age brackets that were underage and hence, not eligible for the questionnaire survey while the red shades showed those above the age and are also not eligible due to poor sight or difficulty in comprehending complex ideas.

The population size, therefore, is about 57% of the entire population of each of the study areas.

Questionnaire Respondents

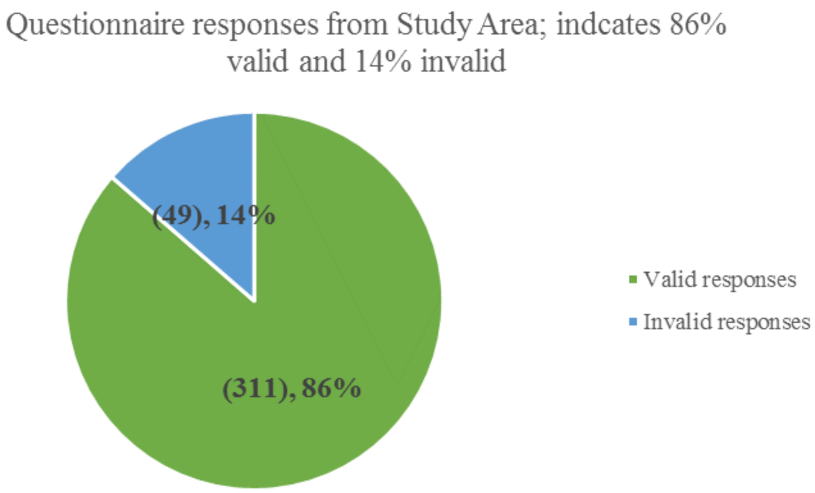

Figure3: Analysis of Valid Percentage for Study Questionnaires.

ISSN 2229-5518

Table 15: Percentage Influence of the Various Flood Indices

Indices	Criteria Weight	Percentage Influence (%)
Land-use	0.061413	6.14
Soil composition	0.020388	2.04
Population	0.062779	6.28
Natural drainage	0.1406	14.06
Slope	0.212984	21.30
Elevation	0.329975	33.00
Availability of manmade drains	0.100477	10.05
Average rainfall intensity	0.035359	3.54
Flow accumulation	0.036028	3.60
∑ (SUM)	**1.000000**	**100**

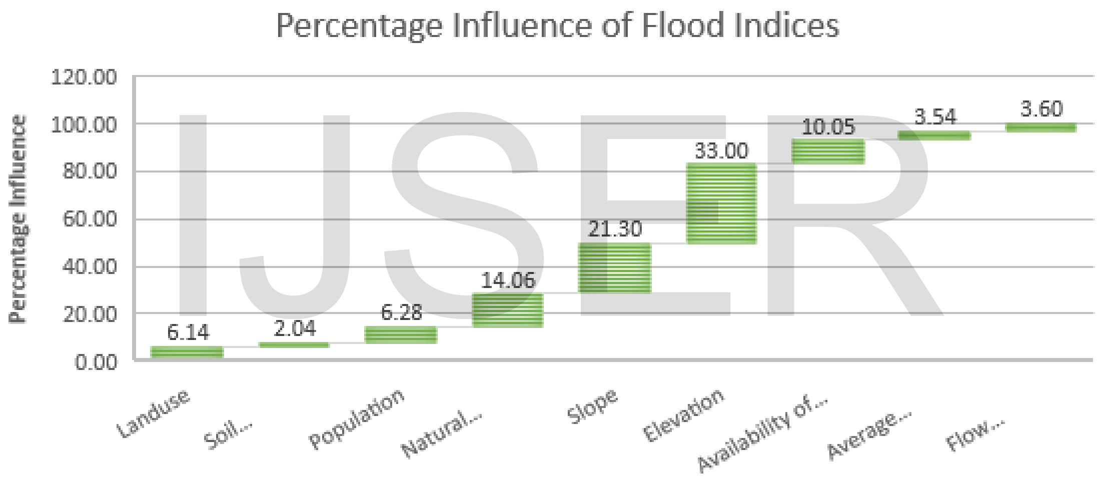

Figure 4: Percentage Influence of the Various Indices Identified.

The Figure 4 showed that Elevation (33%), Slope (21.30%), Natural drainage (14.06%) and Availability of Manmade Drains (10.05%) are the four (4) most influencing indices. Land-use (6.14%) and Population (6.28%) shared almost the same influence or weight while Average Monthly Rainfall Intensity (3.54%) and Flow Accumulation (3.60%) shared the same range of influence and finally, the Soil composition (2.04%) was the least weighted index that could cause flood in the study areas.

4. CONCLUSION

The determination of flood vulnerability indices for solving flood problems in selected areas of Port Harcourt and environs has been studied. The limitations of this study are that it is difficult to get all the data needed to adequately lead this study to a modelling approach largely due to lack of records

ins on the dry land after a particular period of flood, which is taken as the Flood Yield (measured in centimeters, cm) was available.

Study areas were selected based on the observations of a recurring yearly flood cases in the recent years. The field reconnaissance confirmed that the challenges causing the flooding are multi-faceted including rainfall intensity and inadequately designed and poorly managed drainage system, Land-use, Soil composition, Population, Elevation, Slope, Natural drainages or waterways and Flow accumulation. The identified indices were ranked in a pairwise comparison chart using the Analytic Hierarchy Process (AHP) model. The result showed percentage weights of each index having had a Consistency Ratio (CR) of 0.052, a value less than 0.1. This showed that the pairwise comparisons conducted and criteria weights obtained are consistent, dependable and accurate for the decision-making process of identifying indices that determines the flood vulnerability of these selected areas in Port Harcourt.

Recommendations

The study recommended the land elevation; slope, natural drainage and availability of manmade drains must be criteria parameters that should be considered in construction and development of any road or residential project. Also, man-made drainages, catchment, rivers and water ways should be dredged, de-silted and cleared to improve their capacities to contain accumulated flow.

References

Akpokodje, E. (2007): "Flood Risk Assessment," A Colloquium Paper presented at the National Association of Hydrogeologist Conference, Port Harcourt, 5.

Arizona-Ogwu, L. C. (2011): "Port Harcourt PDP Rally Stamped: Irregular or Deregulated Police Action?" Nigerians in America. Retrieved 25 June 2014.

Atedhor, G.O, Odjugo, P.A.O and Uriri, A.E. (2011). Changing Rainfall and Anthropogenic-induced Flooding: Impacts and Adaptation Strategies in Benin City. Nig. Jour. of Geo. and Regional Planning. Vol.4(1) pp.42-52.

Caldwell, D.B. (2012). Definitions and General Terminology. Operations and services, Hydrological Programs. National weather service manual 10-59. Retrieved February 11, 2013 from http://www.nws.noaa.gov/directives/.

Chiadikaobi, K.C., Omoboriowo, A.O., Chiaghanam, O.I., Opatola A.O. and Oyebanji, O. (2011): Flood Risk Assessment of Port Harcourt, Rivers State, Nigeria. Advances in Appl. Sci. Res., Vol. 2(6): 287-298.

Conserve Energy Future (2019): Top 25 Environmental Concerns. Retrieved on May 28, 2019. https://www.conserve-energy-future.com/top-25-environmental-concerns.php

City Population (2019: Obio/Akpor Local Government of Nigeria – Population. Retrieved on June 6, 2019. https://www.citypopulation.de/php/nigeria-admin.php?adm2id=NGA033015

Crowther, S. (2018): The Impact of Flooding on the UK Transport System. Retrieved June 2018. https://www.railpro.co.uk/railpro-magazine/june-2018/the-impact-of-flooding-on-the-uk-transport-system

Demographia (2016): Demographic World Urban Areas. 11th Ed. Retrieved 7 September, 2016.

Denscombe, M. (2010): The Good Research Guide, 4th Edition, Open University Press, Mc Graw-Hill Education, United Kingdom. pp389

Duru, P. and Yusuf, U. (2012). River Benue Surge: Disaster hits Makurdi. Vanguard September 12 publication. Retrieved February 18, 2013 from http://www.vanguardng.com/2012/ogriver-benue-surge-disasterhits-makurdi/.

Elenwo, E. I., (2015): Assessment of the Activities of Scavengers in Obio/Akpor Local Government, Rivers State, Nigeria. J. of Env'talProctection, Scientific Research Publishing. Vol. 6. pp272-280.

Eludoyin O.S. and Weli V., (2010). Spatial Analysis of Flood Vulnerability Levels in Port Harcourt Metropolis Using Geographic Information Systems (GIS), Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt, Nigeria.

Ezemonye, M.N and Emeribe, C.N. (2011). Flood Characteristics and Management Adaptations in parts of the Imo River System. Ethiopian Journal of Environmental studies and Management. Vol. 4(3).

Geoff Garrett A. O. (2011): Understanding Floods: Questions and Answers. A report of the 2010-11 Flood by Queensland Flood Commission of Inquiry. pp. 1-38.

Ishaya, S., Mashi, S.A., and Ifatimehin, O.O., (2008): "Application of Remote Sensing and GIS Techniques in Mapping Areas Favourable to Fadama Farming in Gwagwalada, Abuja, Nigeria." American-Eurasian Journal of Sustainable Agriculture, Vol. 2(3), pp 196-204.

Jenkins, R. (2011). Health Risks Remain after Flood Subsidies. Retrieved February 18, 2013 from http://www.abc.net.au/health/features/stories/2011/02/10/3135043.htm.

Khalid, I. (2012): Nigeria: Deadly Flooding in Jos in Plateau State. BBC News in 24th June 2012. Retrieved on July 4, 2019. https://www.bbc.com/news/world-africa-18966160

Kolawole, O.M, Olayemi, A.B, and Ajayi, K.T. (2011). Managing Flood in Nigerian Cities: Risk Analysis and Adaptation Options. Scholars Research Library Vol 3(1) pp17-24

Kunz, J. (2010): "Analytic Hierarchy Process," An online presentation made to the Eagle City Hall Location Options Task force. Available at: https://www.slideshare.net [Accessed 13 Oct. 2014]

Morristown, T.N., (2010): Definition of flood and flash flood. Retrieved February 11, 2013 from http://www.5rh.noaa.gov/mrx/hydro/flooddef.php.

National Bureau of Statistics (2018): National Population Estimates 2006-2016 – Population Forecast based on the 2006Census of the National Population Commission. pp1-10.

Neussner, O., Obermaier, I. and Sanchez, A. (2012): Application of a Digital Elevation Model for Flood Modelling for the Pagsangaan River in Leyte, Philippines.

Nobre, C.A., Young, A.F., Saldiva, P.H.N., Orsini, J.A.M., Nobre, A.D., Agura, A.T., Thomaz, O., Parraga, G.O.O., Silva, G.C.M., Valverde, M., Silveira, A.C. and Rodrigues, G.O. (2011): "Vulnerability of Brazilina Megacities to Climate Change: The Sao Paulo Metropolitan Region (RMSP). Climate Change in Brazil: Economic and Regulatory Aspects. Brisilia: IPEA." pp197.

Nur HishaamSulaiman, Mohd Khairul Amri Kamarudin, MohdEkhwanToriman, HafizanJuahir, Frankie Marcus Ata, Azman Azid, Noor Jima Abd Wahab, Roslan Umar, Saiful iskandarKhalit, MokhairiMakhtar, Amal Arfan and UcaSideng (2017): "Relationship of Rainfall Distribution and Water Level on Major Flood 2014 in Pahang River Basin, Malaysia," The International Journal of Thai Society of Higher Education (TSHE) Institute on Environment – EnvironmentAsia 10 (1), pp1-8.

Olayinka, D.N. and Irivbogbe, H.E., (2017): "Flood Modelling and Risk Assessment of Lagos Island and Part of Eti-Osa Local Government Areas in Lagos State," Journal of Civil and Environmental Systems Engineering, UNIBEN, Vol 15(1), pp 106-121

Ologunorisa, T.E. (2009): Strategies for Mitigation of Flood Risk in the Niger Delta, Nigeria. J. Appl. Sci. Environ. Mgt. Vol. 13(2) pp 17-22.

Ologunorisa, E.T. (2001): An Assessment of Flood Risk in the Niger Delta, Nigeria. Unpublished Ph.D. Thesis, University of Port Harcourt, Nigeria, 303pp.

Saaty, T.L., (1980): "The Analytic Hierarchy Process." McGraw-Hill, New York.

Saaty, T.L., (2008): "Decision Making with the Analytic Hierarchy Process." International Journal Services Sciences, Vol. 1(1), pp.83–98.

Terungwa, U. P and Torkwase, I. C. (2013): Current Issues in Flood Disaster: Challenges and Implication for Science and Technology to Enhance Environmental Education, Acad. J. for Interdisciplinary Stu., Vol. 2(6), pp61-65.

Ukpaka C.P and Ukpaka C. (2016): Characteristics of Groundwater in Port Harcourt Local Government Area, Chemistry International Journal, Vol 2(3), pp136-144.

United Nations Office of the Coordinator of Humanitarian Affairs (OCHA) 2008: Situation Report 5-Southern Africa Floods. 31 January

United Nations Office of the Coordinator of Humanitarian Affairs (OCHA) 2012: Annual Report

United States Department of Agriculture (USDA) (1989): Soil Conservation Services – "Engineering Hydrology Training Series – Module 105 – Runoff Computation." pp1-37.

Vitor, V. V., Ciro, L. V., Follador, M. and Amoni, M. S. A. (2017): Floodable Cross-sectional Area and Slope to the Nearest Drainage as Extension of the HAND Model: Mapping Flood Susceptibility in the Region of Lucas DO Rio Verde, Mato Grosso State, Brazil. GeoAmazonia Belem, Vol. 05 (09), pp03-25.

W.H.O. (2002). Floods: Climate Change and Adaptation Strategies for Human Health. Report on a W.H.O meeting, London, United Kingdom.

Wizor C. H. and Week, D. A., (2014): "Geospatial Mapping and Analysis of the 2012 Nigeria Flood Disaster Extent in Yenagoa City, Bayelsa State, Nigeria." Journal of Environment and Earth Science, Vol.4(10), pp64-77.

Yamane, T., (1967): Statistics: An Introductory Analysis. 2nd Edition, Harper and Row, New York.