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Flood Vulnerable Area Assessment of Abakaliki Metropolis South-eastern Nigeria.

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ABSTRACT
As a result of global warming, the climate change in Africa and Asia is predictably becoming more variable, and weather events expected to go more frequently extreme and severe. This includes increasing risk of drought and flooding in new areas. Inundation by extreme floods events is recorded every year worldwide. The potential consequences are profound increasing risk, particularly on environment and people in the less developed countries. Flooding cannot be totally avoided and maybe their occurrence will increase due to climate change. Absolute protection is both unachievable and unsustainable because of high costs and inherent uncertainties. Abilities to mitigate and or prevent flood disasters, cope with and recuperate from the effects have not been sufficiently taken into account nor developed. Communities within watershed or along the River system such as Abakaliki metropolis are mostly under threat of constant flooding menace. When flooding strike, the poor and socio-economically disadvantaged suffer the most and are least equipped to cope with impacts. Vulnerability assessment which many regions of the world recently commenced becomes the way forward. Assessing vulnerability and impacts requires and analysis of information on climate elements, such as temperature, rainfall and non-climatic data, such as situation on the soil, altitude and other characteristics of elements-at-risks indicators. This informs for a well thought-out monitoring (risk assessment), mitigation, coping strategies and adaptation measures which can be adopted by all the vulnerable stakeholders including Governments at all tiers.
Keywords: climate elements, element-at-risk, flood, global warming, stakeholders, vulnerability.

I. INTRODUCTION

In recent times most regions of the world are experiencing economic losses due to natural hazards. Disasters such as floods have increased in many folds and have resulted in loss of human lives and livelihoods, destruction of economic and social infrastructure, as well as environmental damages (Munich, 2002). Flood could be seen as one of the most common natural disasters in the world. Flood is said to be the most significant effect of climate change on the poor (Idowu, 2011). Mustapha, (2005), noted that various physical, social and technological factors intersect to make flood hazard a “hybrid hazard”. Flood is one of natural hazards resulting from combined extreme natural processes (climatological, geographical, geological, geophysical and hydrological) and interrelationships cum anthropogenic activities to create an unexpected threat to environment, human life and property. When floods occur, they can create natural disasters involving loss of human life and property plus serious disruption to developmental activities of communities (Smith and Ward, 1998). Communities within watershed, along or close to the River plain system terrain such as Abakaliki metropolis are mostly under threat of constant flooding menace. Severity of damage by flood hazards depends on the vulnerability of exposed elements and flood characteristics. Interestingly most settlements of the world are within river floodplain threshold or are at the high risk factor rating thereby being vulnerable.

Vulnerability refers to inherent characteristics of an element which determine its potential to be harmed (Sarewitz et al. 2003, UN/ISDR., 2004a). It is the susceptibility or level of proneness of an element (individual, property or environment) to the negative impacts of hazards. Generally, an element at risk of being harmed is the more vulnerable, the more it is exposed to a hazard and the more it is susceptible to its forces and impacts.

Moreso, vulnerability can be associated with the flood characteristics i.e. capabilities regarding matter fluxes (debris, sediment), water depth, flow velocity and temporal and spatial dynamics and other substances (e.g. toxic) substances with varying impacts on elements. Vulnerability of elements requires information analysis regarding specified factors of element-at-risk indicators, exposure indicators and susceptibility indicators. Factors affecting a property or an environment’s resilience or the adaptive capacity to the impact of flood hazards make it susceptible or exposed to flood. It further depends on both the type of flood event and the constitution.

Vulnerability is a critical dimension of poverty, synonymous with poverty, refers to defenselessness and insecurity (Idowu, 2011). With the increasing number of settlements within flood high risk rating area worldwide, the number of people at risk or vulnerable to flood hazards is likely to increase. Any increase in disasters, whether large or small, will threaten development gains and hinder the implementation of the Sustainable Development Goals. Flooding, poses serious challenge to the development and economy of a nation- economic environment, financial systems, social welfare, power sector, transportation, investments, commerce, manufacturing, construction and banking among others. However, beside the negative impact of flood, there can be some positive impacts, for instance, increased fertility of agricultural land (Parker et al. 1987) and improved water transportation and viability of hydropower.

Disasters when they occur usually result in pains and huge losses to the economy making the positive impacts insignificant and in most cases, it is always difficult to quantify the actual cost of damages and recovery. For the less privileged or vulnerable communities or groups, some of the impacts are very direct and can have knock-on effects. They are the most vulnerable socially, economically and physically to the impacts of extreme events and, to the impact of adverse environmental tendencies resulting from climate change such as flood. Research has shown that about 85 percent of households vulnerable to flooding live in developing countries and as a result, such countries experience the majority of flood-related deaths (ProAct Network 2008, IPU/ISDR, 2010). One of the countries that rank high among such vulnerable countries is Nigeria (ISDR and World Bank 2009).

A case of flood disaster such as the one that occurred in most cities in Nigeria including the study area in July-October, 2012 actually destroyed several years of developmental efforts, (Shamonda, 2013). There were loss of lives and livelihoods, destruction of public utilities and disruption in the smooth functioning of the system that renders fear and uncertainties among the populace. In addition, there was damage to the environment, financial loss, and diversion of resources, epidemics, migration, food shortages and displacement of the people. The impact was very high in the urban areas due to population density. A more disgusting issue is the lack of attention to the promotion of sustainable environmental management especially in flood disaster prone areas such as the study area resulting in devastations which could have been averted. The poor, priorly unplanned and developing urban usually characterized by various forms of social deprivation, including low education, low and unstable income, struggle for survival and a spatial infrastructural mismatching with all the antecedents of slums, shanty or squatter settlements as epitomized in the study community aggravates vulnerable susceptibility.

The devastation caused by floods is exacerbated by low level of awareness of flood incursion spatial area. Floods cannot be totally avoided and their occurrence is the increase due to climate change. If the capacity for assessing climate variability, impacts and vulnerability of an area to climate change is not there, countries are limited in their ability to plan adaptation measures and adapt effectively (UNFCCC, 2008). Vulnerability assessment which many regions of the world have commenced becomes the way forward. Consequently, the need to undertake this study, delineate high risk to flooding impact in Abakaliki metropolis as a guide to development of the fast developing town. This study, therefore, intends to contribute to the body of knowledge in environmental planning, by examining flood prone area in Abakaliki metropolis, Nigeria.

II. STUDY AREA

2.1 Geology and Structure

The underlying rock in the area is the Abakaliki shale which lies within the Asu River Group of mid Albian age in the Southern (Lower) Benue trough Nigeria. The Abakaliki shales are poorly bedded, occasionally sandy and consist of metamorphosed mudstones. Lenses of sandstone and sandy limestone are also found. All these rock types are fossilified, highly jointed and fractured.

The geologic history of Abakaliki basin is characterized by compressional tectonic stresses. The associated stresses caused metamorphism, folding and fracturing of older marine and volcanic rocks. Primary porosity is low due to lithologic conditions. The low primary porosity suggests very poor groundwater infiltration, transmission and storage capabilities; however, the development of secondary porosity by fracturing and faulting has led to increase in the bulk permeability of the fractured shale. Secondary porosity is better developed at large-scale and observed on surface outcrops. Groundwater flow is largely controlled by fracture and transmitted through an interconnected network of the cracks- fissures. The network of fissures in the rock is often complex having different widths, depths and orientations which mean that water moves at very different rates in different fractures. These structures are mostly parallel and cross-cutting (Reyment, 1965).

However, in general, groundwater moves at a relatively slow velocity through the tortuous network of the interconnected fractures in the bedrock.

The topographical characteristics of the area comprises of undulating plain with irregular ridges and gentle sloping hills (low hills). The main relief is an elongate ridge- the Abakaliki anticlinorium. These topographical features were seen to be controlled by the bedrock geology; capped by the highly weathered shales occupying the area. The weathered rusty brown to reddish brown shales were mainly exposed by road cuts and erosion surfaces, while the dark grey or black shales were mainly exposed occasionally by river channels.

2.2 Location

Abakaliki is in Southeastern Nigeria. Abakaliki metropolis is located in the Cross River Basin area of Nigeria hydrological province and precariously placed in the mid Ebonyi river watershed and tributaries, fig 1. The metropolis is supposedly on flood high risk area rating in terms of flood vulnerability.

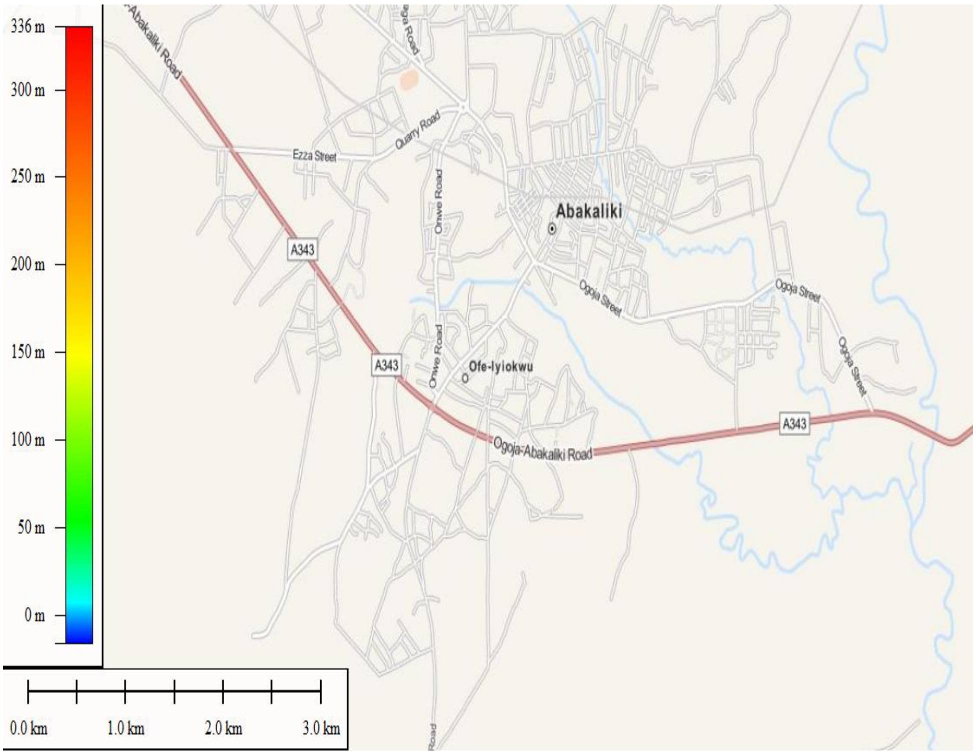

Fig 1. Map showing Abakaliki metropolis roads network, settlement and major drainage

2.3 Weather and Climate

Two main seasons dominate the climate of the area– rainy (late April-October) and dry (November-April). Annual rainfall is 1000 to 2000mm and monthly rainfalls vary from 50 to 300mm while August has 180 to 200mm of rain (Iloeje, 1981).

Records show a mean annual temperature of 31.2^{0}C ranging from 33^{0}C in dry season to 28^{0}C in wet season. The seasonal climatic conditions are caused by "the North-South fluctuations of a zone of discontinuity between the dry continental (Saharan) air and the humid maritime (Atlantic) air. At the surface, it forms a boundary― Surface of Discontinuity (Iloeje, 1981). Other minor climatic conditions in the area are the short dry season― August break and the harmattan patches of November to February. Meanwhile, the greenhouse effect of the climatic change is gradually eroding the cold harmattan patches and its occurrence sparingly noticed nowadays.

2.4 Soil types, Vegetation and Drainage

The area is characterized by reddish brown ferruginized gravel and pale brown clayey soils derived from shales. Two main soil types are found in Abakaliki area– silty clay hydromorphic soil and the grey sandy clay hydromorphic soil. These form clayey swamps (flood plain) suitable for rice farming. The area falls within the rainforest/savannah belts. The lush vegetation is characterized by variety of tree shrubs, grasses and palms. The vegetation is Parkland, which is derived savannah. This is characterized by stunted trees and pockets of derelict woodland and secondary forests consisting of few shrubs with dispersed large trees and sparse climbers.

The area is a gently sloping drainage basin. Runoff is high during rainy season courtesy the lithology. Surface water bodies flourish during the rainy season and most of them dry up during the dry season being probably geologically controlled via the structures. The drainage system is dendritic. The flow patterns recorded in the research area are that of the irregular dendritic patterns which consist mainly of a number of small ephemeral streams which are moderately to imperfectly drained. The parent course is the Ebonyi River, Fig 1. Other drainage channels include the Iyi okwu and Iyi udene streams. Generally, the water course flows eastward to join the Cross River, somewhere outside the research area.

III. METHODOLOGY

Information and data available from meteorological and hydrological centres were examined. Basin morphormetric parameters of drainage system – pattern, density, stream frequency and texture were analyzed using topographic maps as a basis for making hydrogeologic inferences. The parameters were evaluated using empirical relationship of Ritter (1981) shown in Table 1. Climatic and non-climatic records from FUNAI synoptic station were monitored, obtained and analysed. Climatic elements data of the area obtained from FUNAI synoptic stations for some period is as in tables 2-5.

Table 1: Morphormetric relationship used in characterizing study area basin (after Ritter, 1981)

S/N	Morphormetric	Empirical Relation
i. ii.	Drainage Density (D) Steam Frequency (F)	$D = \Sigma L/A$ $F = N/A$

Where A = area of basin
ΣL = total length of Streams

Table 2. Weather Data, January – June, 2016. Source: FUNAI

	Rainfall (mm)		Temperature (°c)		Evaporation		Dew point (°c)		Vep. Pressure (mbs)		Relative humidity (%)		Wind run (km)	Sunshine (hrs)
	Amt	Day	Max	Min	Tank (mm)	Piche (ml)	0900z	1500z	0900z	1500z	0900z	1500z		
Jan	0.0	0	35	22	6.0	10.9	14.7	13.0	17.7	15.3	45	27	108	7.1
Feb	9.3	1	38	24	5.9	9.3	19.4	15.1	24.8	18.4	55	29	126	6.2
Mar	159.1	8	34	24	3.6	3.8	25.9	25.9	33.6	33.7	83	68	131	4.8
Apr	63.8	7	35	25	3.9	3.7	26.1	26.2	33.8	34.2	83	70	123	6.5
May	284.7	15	34	25	3.6	3.0	25.5	26.2	32.8	34.2	84	71	114	6.8
June	103.3	14	31	24	2.7	2.8	24.1	24.7	30.1	31.3	84	73	103	4.9
July	284.5	21	31	24	2.4	1.8	24.1	24.6	30.1	31.0	89	78	100	3.7
Aug	239.3	21	30	23	2.4	2.0	24.0	24.7	38.6	31.3	88	79	106	2.5
Sept	205.0	18	31	23	2.9	2.3	24.2	24.5	30.2	30.9	85	73	103	3.8
Oct.														
Nov.														
Dec.														
Total														

Table 3. Weather Data, January – June, 2015. Source: FUNAI

	Rainfall (mm)		Temperature (°c)		Evaporation		Dew point (°c)		Vep. Pressure (mbs)		Relative humidity (%)		Wind run (km)	Sunshine (hrs)
	Amt	Day	Max	Min	Tank (mm)	Piche (ml)	0900 Z	1500 Z	0900 Z	1500 Z	0900 Z	1500 Z		
Jan	0.0	0	35	22	6.0	8.4	13.7	13.3	17.9	16.7	45	30	134	6.7
Feb	85.6	3	35	25	4.5	5.2	24.4	21.7	30.6	25.8	74	49	143	6.3
Mar	33.2	4	35	25	4.8	4.5	24.7	22.9	31.2	28.1	76	54	118	5.9
April	83.2	6	35	25	4.9	4.8	24.8	23.1	31.4	28.5	75	52	118	6.5
May	189.1	8	34	24	4.0	3.0	24.4	24.3	30.7	30.4	78	61	118	6.9
June	130.5	15	32	24	2.8	2.1	24.0	24.3	29.9	30.5	83	70	132	4.7
July	214.8	17	30	24	2.6	1.6	23.8	24.3	29.5	30.3	87	73	122	3.6
Aug	215.4	20	30	24	2.3	1.3	23.9	24.5	29.8	30.7	87	76	113	3.0
Sept	313.9	18	31	24	2.4	1.7	24.1	24.4	30.0	30.5	85	71	101	4.0

Oct.	182.9	15	32	24	3.0	2.2	24.6	24.5	30.9	30.8	81	68	98	6.1
Nov.	82.1	3	34	24	3.7	3.3	24.5	22.3	30.9	27.1	79	54	80	7.5
Dec.	0.0	0	34	22	6.7	10.4	9.0	13.2	11.9	15.4	31	30	112	7.5
Total	1530.7	109												

Table 4. Weather Data, January – December 2014. Source: FUNAI

	Rainfall (mm)		Temp. (^{o}c)		Evaporation		Dew point (^{o}c)		Vep. Pressure (mbs)		Relative humidity (%)		Wind run (km)	Sunshine (hrs)
	Amt	Days	Max	Min	Tank (mm)	Piche ml	0900 z	1500 z	0900 z	1500 z	0900 z	1500 z		
Jan	0.0	0	34	21	4.5	5.9	20.5	17.8	25.5	21.4	65	40	-	-
Feb	38.3	2	36	23	5.6	6.6	22.8	18.2	28.6	22.0	79	38	107	7.7
Mar	76.2	5	34	24	4.4	4.2	24.9	24.1	31.5	30.2	79	58	130	6.0
April	118.1	7	34	23	4.3	4.2	24.5	24.4	30.9	30.5	76	61	122	7.1
May	348.3	17	33	23	2.9	2.6	24.6	25.0	31.0	31.8	83	66	91	6.3
June	140.5	13	32	22	3.0	2.7	24.4	24.8	30.7	31.4	83	69	117	5.9
July	193.4	17	30	22	2.4	1.9	23.9	23.8	29.6	29.7	85	72	118	3.8
Aug	261.1	15	30	22	2.5	1.9	23.6	23.3	29.2	28.8	85	73	120	2.8
Sept	247.9	22	31	23	2.7	2.0	23.8	23.9	29.5	29.7	86	69	100	4.4
Oct.	169.8	15	32	23	3.1	2.5	24.0	24.1	29.8	29.8	81	66	102	6.1
Nov.	61.9	2	33	24	3.6	2.7	24.3	23.4	30.5	28.9	79	60	89	6.9
Dec.	0.0	0	34	22	4.4	5.0	19.6	18.0	24.4	21.8	62	41	80	6.6
Total	1,655.5	115												

Table 5. Weather Data June –December 2013. Source: FUNAI.

Rainfall (mm)			Temperature (^{o}c)		Evaporation		Dew point (^{o}c)		Vep. Pressure (mbs)		Relative humidity (%)		Wind run (km)	Sunshine (hrs)
	Amt	Days	Max	Min	Tank (mm)	Pich ml	0900 Z	1500 Z	0900 Z	1500 Z	0900 Z	1500 Z	NIL INSTRUMENT	NIL INSTRUMENT
Jun	209.6	14	32	23	2.7	2.8	24.4	24.5	30.3	30.7	86	71		
Jul	195.4	20	30	23	2.1	2.1	23.9	24.4	29.9	30.5	91	79		
Aug	224.6	17	29	23	2.2	2.0	24.0	24.4	29.9	30.7	90	79		
Sept	193.1	13	30	23	2.6	2.2	23.8	24.1	28.7	30.4	87	73		
Oct	207.7	16	31	23	2.6	2.4	23.7	24.0	29.5	29.9	82	67		
Nov	172.3	4	32	23	3.2	2.8	24.3	23.7	30.4	29.4	80	63		
Dec	37.3	3	32	21	3.6	3.9	20.8	19.7	29.5	23.3	71	49		
Total	1240.0	87												

Soil characteristic of Transmissivity values were estimated using hydraulic conductivity values typical of fractured and unfractured clays as provided in Freeze and Cherry (1979) and thicknesses ranging from 20 to 25m as estimated from the available lithologs of the study area. The transmissivity (T) relation of the form,

$$T = K_{f,n}b \ldots\ldots\ldots\ldots (1)$$

Where K is the hydraulic conductivity, the subscripts f, n refer to fractured and unfractured conditions respectively and b is the clay thickness.

Typical **K** values and the clay thickness are

$K_f = 10^{-8}$m/s
$K_n = 10^{-10}$m/s
b = 22.60m

Substituting the respective values into relation (1) and simplifying, provides for T values of 2.26^{-06} m^2/s and 2.26^{-08} m^2/s for fractured and unfractured scenarios respectively.

Other data and information collated on morphormetric parameters were evaluated to ascertain catchment characteristics include the following: Major dams/reservoirs locations close to the study area, Land use, vegetation, settlement and DEM maps from satellite imageries.

Channel geometry (depth, width and mean flow velocity) was also estimated at several locations along the water courses to enable the determination of stream discharge. The flow velocity was measured using a float. The surface velocity so measured was converted to mean flow velocity. Stream discharge (Q) was calculated using the relation:

$$Q = VA\ldots\ldots\ldots\ldots (2)$$

Where V is mean flow velocity and A is cross-sectional area.

Using the relation (2), Q for Ebonyi River and two of its tributaries (Iyi okwu and Iyi udene, Fig 1) was estimated. Artificial surface water storage facilities nearest to the study area is the Ezillo Regional Water Scheme. Its operational capacities were obtained from the relevant water agencies.

IV. RESULT

The drainage system consists of Ebonyi River (major) and its tributaries. The soil and rock type is hydromorphic clay and shale respectively. Transmissivity value of 2.26-06 m2/s calculated for fractured clay is indicative of low transmissivity environment such as clay and shale. The drainage texture is typical of medium to fine. Drainage pattern is dendritic and density is relatively high. These indicate homogenous, impervious rock, soil of low permeability and poor infiltration hence high to medium levels of surface run-off. Stream discharge varies from 5.8 m3 s-1 (5800 l/s) in the upper reaches of the tributaries to 29.6 m3 s-1 (59600 l/s) in the main Ebonyi River. This (59600 l/s) serves as estimated total run off or total discharge across the entire area during the rainy season. This is high and hence consistent with Offodile (2002) which states that high runoff.

The results of the analysis were presented in the following charts:-

(i) Charts showing rainfall, figs 2 – 5.

(ii) Map showing flood incursion extent, figs 7 and 8.

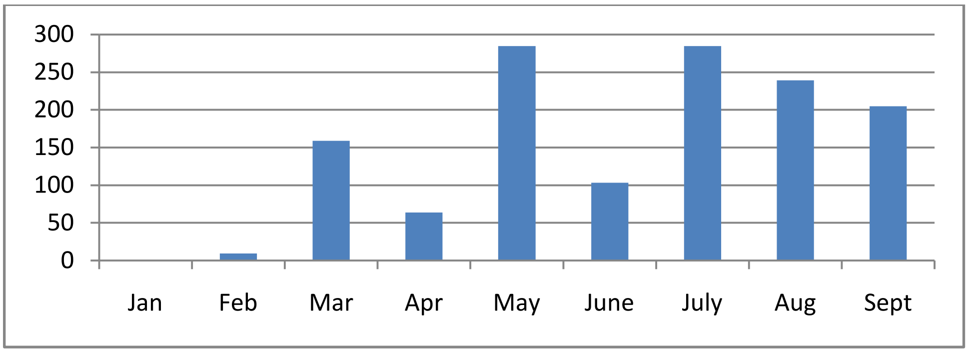

Figure 2. 2016 rainfall

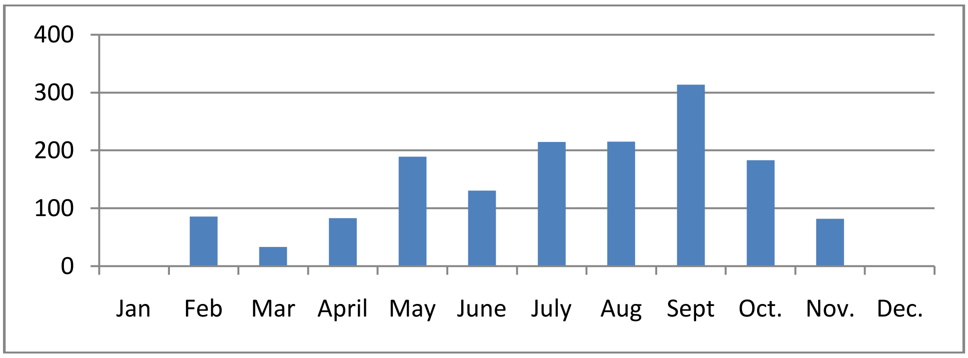

Figure 3. 2015 rainfall

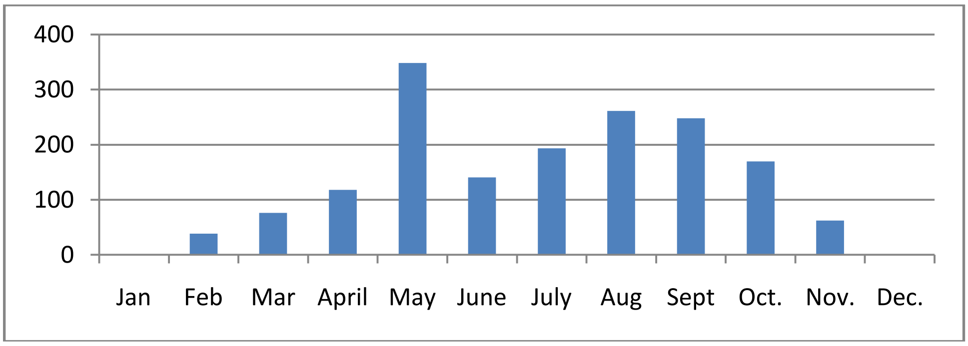

Figure 4. 2014 rainfall

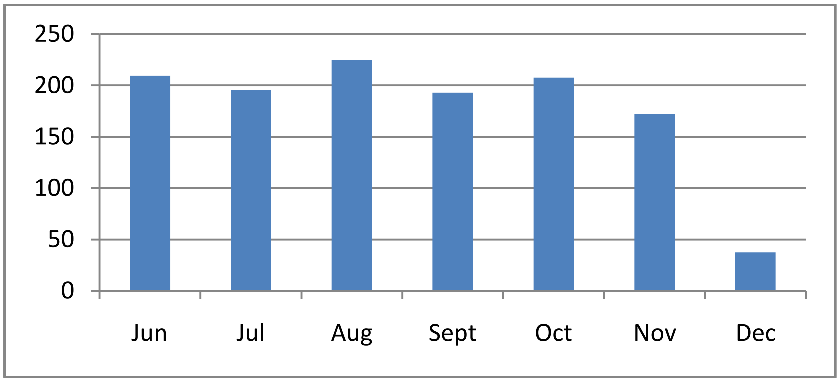

Figure 5. June-Dec. 2013 rainfall

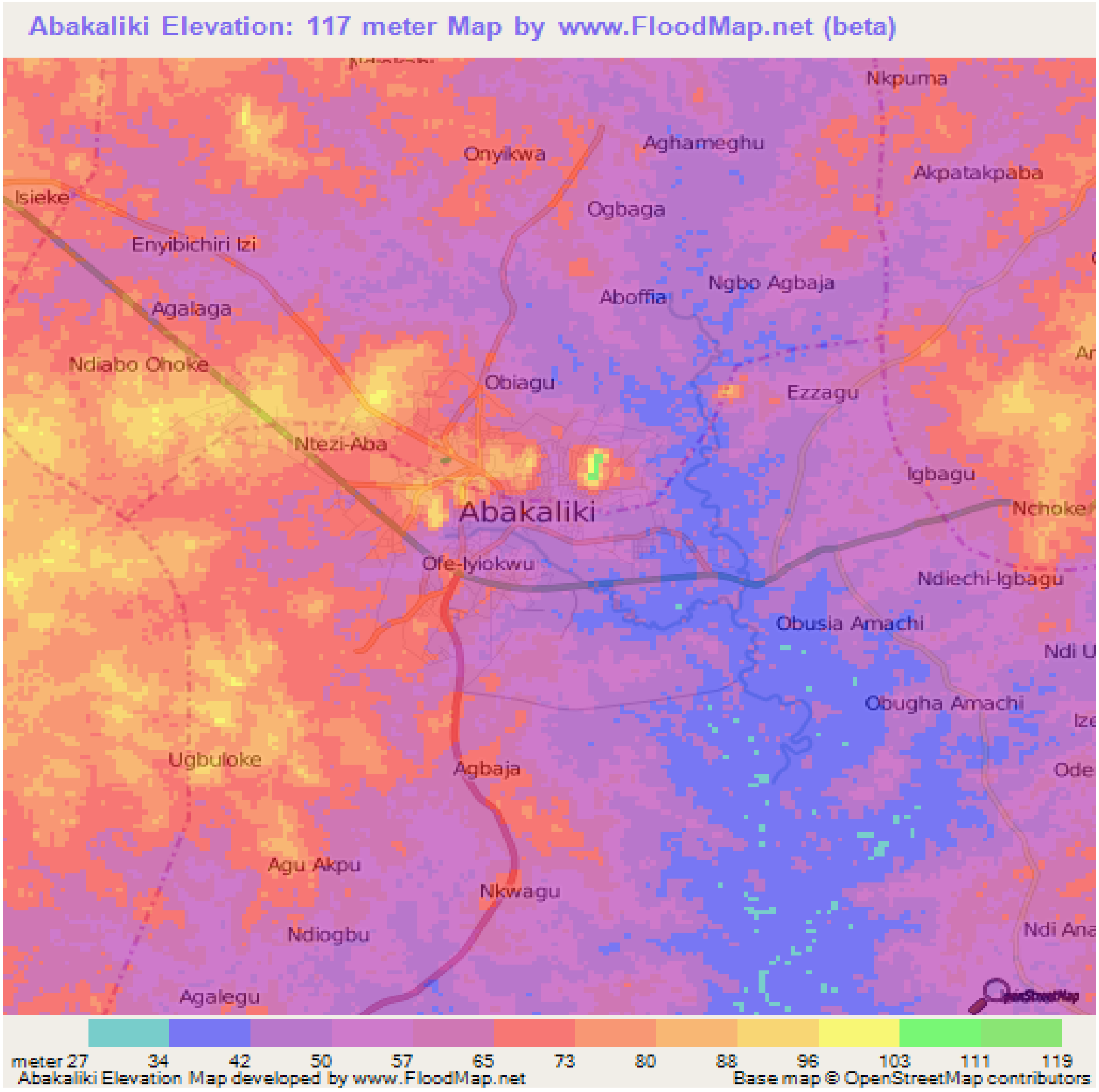

Fig 7. Flood incursion map of Abakaliki area and environs

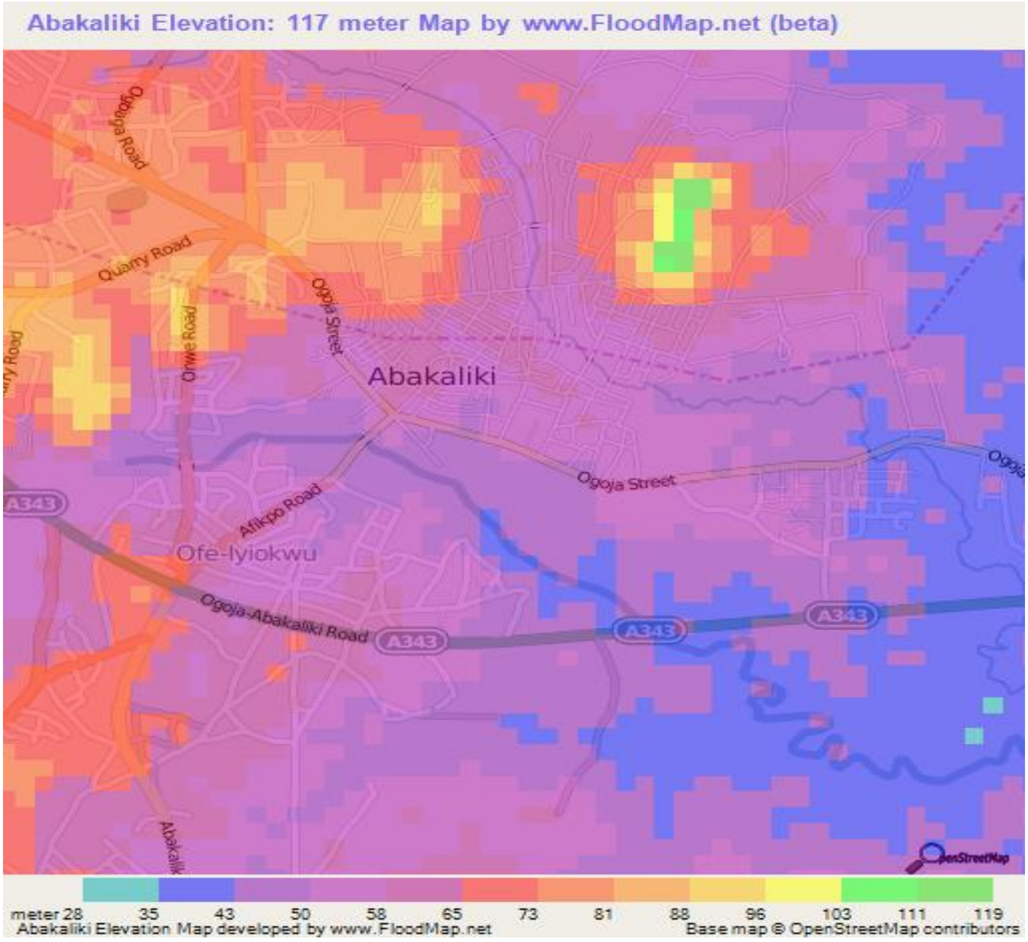

Fig 8. Digitized flood vulnerability map of Abakaliki metropolis.

Rainfall record for the period of three and half years monitored from FUNAI synoptic observatory were represented in figures 2-5 below. The result shows that highest volume of rain begins and reoccurres in the month May. Following the intense rainfall from May the soil moisture reaches saturation, or near saturation and water level rises, figure 6. Further, due to geometric population rise and urbanization, much surface area has been cemented thereby generating overland flow. With these, it is imminent that flood situation may occur. Figure 7 is the flood incursion map of Abakaliki area and environs. Figure 8 is digitized flood vulnerability characterised map of Abakaliki metropolis. Flood vulnerability zoning of element-at-risk using proximity factor rating, table 6 is employed in the delineation of the area. Figure 9, is the vulnerability characterization and delineation map developed for the Abakaliki metropolis.

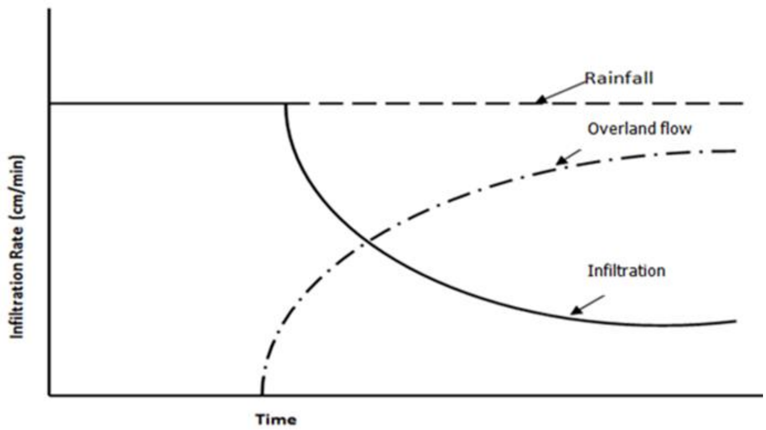

Figure 6. Flood generation mechanism

Table 6. Element-at-risk vulnerability risk factor rating, (modified after Amangabara and Obenade (2015))

Element Distance Away from flood source	Risk Factor or Rating
1,500m Away	Less Risk
1Km Away	Moderate Risk
500m Away	High Risk

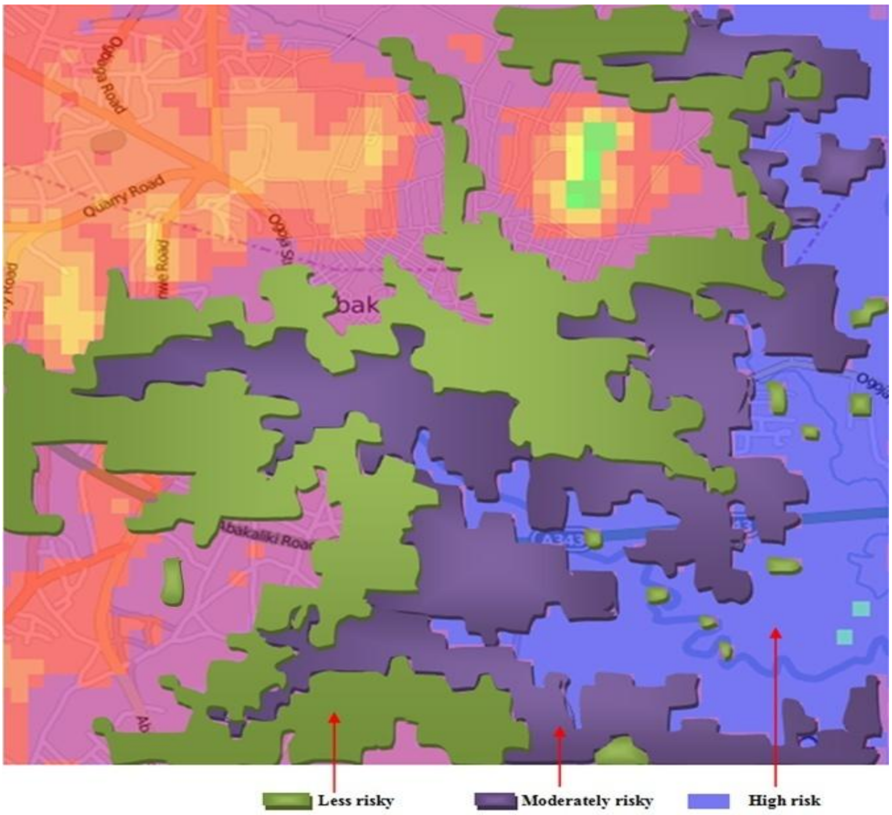

Figure 9. Flooding Vulnerability zone map of the study area

V. DISCUSSION

The flood geohazard of the area is mainly due to rainfall. Potential influencing factors include geology, geographical location, population/urbanization, lack of information, education and planlessness. The geology of the area does not support fast infiltration hence tendency of surface water ponding. Further the expansive soil swells and degenerate to mudfloods. The geographical location of the study area is the floodplain of Iyi okwu, Iyi udene streams and in the watershed of Ebonyi river.

North-East/South-East to the Central parts of the metropolis lie on the flood vulnerable risk area with annual exceedence probability, P_e of 1. Some facilities such as schools, markets, administrative quarters, filling stations and business enterprises are either on the high or moderate risk factor areas being located within < 1,500m to streams and Ebonyi river. Those on less risky areas are however threatened when less recurrence floods occur, for example in 2012, less risky areas were inundated and developmental projects and properties damaged. Further to the exposure indicator, susceptibility of element to the vulnerability is the fast urbanization and recklessness of developers. There are lots of mismatches. Soil type is another factor that contributes to flood generation in the area. The soil shortly gets saturated, becomes impermeable and grows overland flow and ponding.

VI. RECOMMENDATION

The results indicate parts of the study area vulnerable to flood hazards hence developmental projects not advised. The areas delineated less risky are fair to be developed. The areas characterised moderately risky can be developed with further enhancement. The areas earmarked high risky are strongly advised not to be inhabited by humans, animals or built amenities on except for projects such as forestry. Land managers, vendors and users should be able to identify spatial distribution to avert mismatch.

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