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The relative contributions of climatic elements and environmental factors to flooding in Awka urban area

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The aim of this paper was to determine the relative contributions of climatic elements and environmental factors to urban flooding in Awka urban area of Anambra State. Towards achieving this aim, 10 year (2000-2009) meteorological data of temperature and rainfall of the study area were collected from synoptic meteorological station in Awka and data on environmental factors were obtained from both the Anambra State Ministry of Environment and responses were gathered from the administered questionnaire to the respondents. Khosla's formula was employed to estimate flood discharge in the urban area and analysis was carried out with the use of multiple linear regression (MLR). Result of the regression shows that 12 variables exhibited positive signs showing that there is a direct relationship between them and flooding in the town. Also, it was found that both climatic and environmental factors contributed 60% to the explained variation, with the climatic elements alone having 33.7%. Finally, policy and planning implications of the study were discussed, while it was concluded that urgent necessary steps need to be taken to achieve goal 7 of the MDGs in the study area, which is to ensure environmental sustainability by the year 2015.

Key words: Climatic, flooding, synoptic, regression, sustainability.

INTRODUCTION

Urban areas especially those in the developing countries experience various types of disaster in most periods of the rainy season as a result of flooding. The destructive effects of floods in urban areas have been widely recognized in Nigeria (Muoghalu and Okonkwo, 1998; Odemerho, 1993, 2005; Offiong and Eni, 2008; Abaje and Giwa, 2008) and other developing countries in general (Smith, 1999; Obote, 2005; Sithole, 2009). Furthermore, the causes of such urban flooding has been linked to climate factors especially rainfall (Gray, 2005; Sadat, 2009), topography (Eze, 2008; Offiong and Eni, 2008) urban sprawl (Sule, 2004), poor urban planning (Goudie, 1981; Slamaker, 2000) and other environmental factors (Onokerhoraye, 1995). According to IPCC (1990) rapid but unchecked urban development in developing countries together with climate change have been identified as the major causes of flooding in the urban areas of the developing countries. While different views are held by researchers in the field, the problem of flooding has continued to be one of the greatest urban problems in low income countries because of the poor preventive measures adopted by the countries. The volume of water associated with each flood event in some of these urban areas is of such magnitude that it always results in the destruction of lives and property.

Most studies on urban flooding have concentrated

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attention on describing the nature of urban floods, listing the causes of such floods and their destructive consequences on life and property. Some of such studies are too descriptive as they lack necessary scientific basis which therefore could not provide enough theoretical framework for scholars. However, few scholars have empirically investigated the problem of urban flood in Nigerian. They include Muoghalu and Okonkwo (1998) who employed the multiple regression analysis (MRA) to identify nine variables causing the flooding in Awka Town, and out of these three of them namely, the percentage of gravel, percentage of course sand and percentage of medium sand accounted for 92.1% of hydrologic performance of the variance explanation in the city, while Geoffrey (2001) employed time series analysis to predict flood events in Lagos Metropolis. However, there are other scholars who have done some work in the town regarding this area of study. For example, Mike and Onell (2009) isolated some climatic elements giving rise to flooding in the area which include, rainfall intensity, rainfall duration, high temperature and atmospheric humidity, and concluded that rainfall intensity and temperature were significant. Furthermore, Okoro and Basil (2012) tried to assess some environmental factors giving rise to flooding in Awka and concluded that area of impervious cover and topographical disposition of the town are significant factors. Apart from these few works known to the authors, the use of statistical techniques in the study of the problem of urban flooding has been relatively scanty. Also, the need to compare the contribution of climatic elements and other environmental factors to ascertain their relative importance to the cause of urban flooding has largely been ignored in relevant literature. To fill these gaps, this paper intends to statistically assess the relative contributions of climatic elements and environmental factors that influence flood generation in Awka and determine the relative effects of predictor variables.

MATERIALS AND METHODS

Study area

Awka town is located between latitudes 6.24°N and 6.28°N and longitudes 7.00°E and 7.06°E on the South eastern part of Nigerian (Figure 1). The study area covers 144.5 ha with a 2006 contested population of 116, 208 persons (NPC, 2006). This includes such outlying communities as Amawbia, Okpuno and Amansea which are fastly being annexed to the town by urbanization. The town's topography presents a rugged relief as it lies completely on Awka-Orlu upland.

Generally, the average height of the town range from 91 m in the western parts of the town to 160.2 m in the eastern zone, although there are local variations within the town which are drained by a number of streams. The climate is the tropical wet and dry type according to the Koppen's classification system with a clear cycle of season. The mean daily maximum temperature is usually 27°C all over the year although it could reach 34°C in March and lowest during the harmattan months of December and January. The mean annual rainfall according to the local meteorological station which has maintained climatological records since 1978 reveal a mean rainfall of about 1600 mm with a relative humidity of 80% at dawn.

Data collection

Ten (10) years (2000-2009) meteorological data of temperature and rainfall of the study area were collected from the Nigerian Meteorological Agency (NIMET) Synoptic Station at Amawbia, while data on environmental factors were obtained from questionnaire responses, field observation and published (secondary) data from the Anambra State Ministry of Environment, Awka. A total of 900 questionnaires were administered for six months, April to September, 2010 with the use of stratified sampling technique with each ward in the town forming a strata. There are nine wards in Awka town, and 100 questionnaires were administered to each of them. The data collected were used to crosscheck the veracity of environmental data collected from the Ministry. Also, *Khosla's* formula was used to estimate flood discharge in the urban area:

$$Q = P - 0.4813Tm \text{ (when } Tm > 4.5°C) \quad (1)$$

Where, Q = yearly or monthly flood discharge in cm; P = yearly or monthly rainfall in cm; Tm = mean yearly or monthly temperature in °C

Data analysis

The formular for estimating flood discharge was used to determine the flood generation in twenty flood channels in the town which was calculated to be 161.290 m^3 in six months, while we obtained the temperature and rainfall data from the NIMET station in the area. We had to carefully identify, define, describe and parametize the range of environmental and climatic factors (Table 1). The parametization was achieved by adding up the number of times a particular variable occurred in the study area during the period of data collection or record readings with respect to climatic variables.

The quantity of flood generation within the period was used as depended variable and the meteorological and environmental factors as independent variable ($X_1\ X_2 \ldots X_n$). The data generated (dependent and independent variables) were subjected to analysis using the multiple linear regression (MLR) analytical technique. The general expression of multiple linear regression as given by Anyadike (2009) is shown below:

$$y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots b_n x_n + e \quad (2)$$

Where y = dependent variable; $x_1\ x_2 \ldots x_n$ = independent variable; a = base constant; e = error term or the proportion of the variance not explained, y the regression.

When the MLR package was used in computer calculation, it was found that the combined relationship between the 14 predictor variables (12 environmental and 2 climatic variables) and the amount of flood generated in Awka town yielded a Multiple Correlation Co-efficient (R) of 0.75 with a co-efficient of multiple determination (R^2) of 0.600. This means that the 14 predictor variables combined to explain or account for 60% of the variations in the amount of flood generation in Awka in 10 years. This, however, leaves 40.0% which the multiple regression model was unable to explain. This shows that other factors outside the climatic and environmental factors utilized in this study also account for flooding in the town. The summary of the result of the performances of the individual variables is shown in Table 2.

A similar analysis was also performed for individual years within

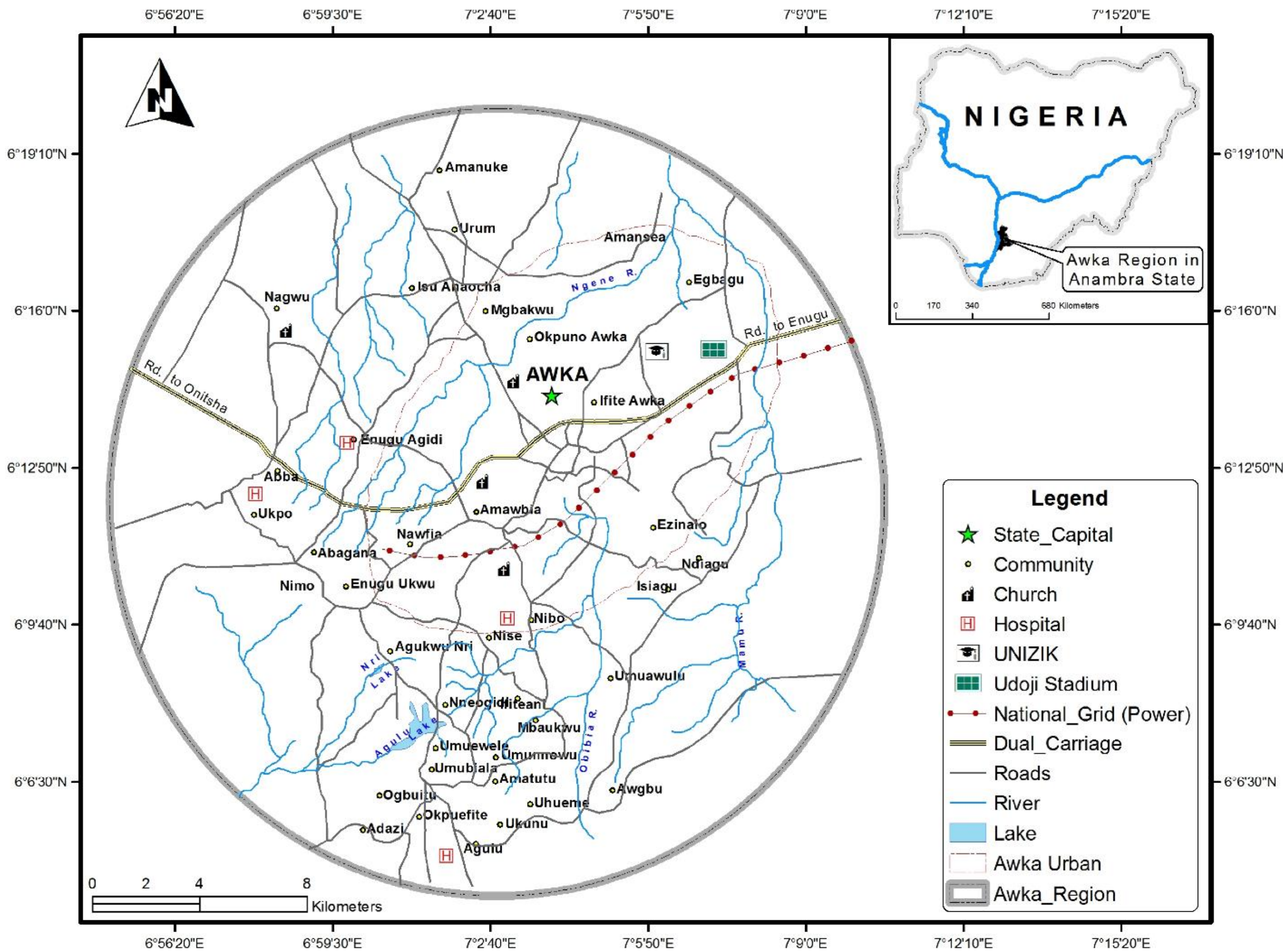

Figure 1. Map of Awka urban area, Nigeria.

Table 1. Description and parametization of climatic and environmental factors influencing flood generation in Awka town.

Name of variable	Variable label	Method of parametization
Number of flood channels used for dumping refuse	REFU	The number of flood channels used for dumping refuse during the period of data collection was determined and recorded
Number of flood channels with reverse gradient	GRAD	The identified number of flood channels with reverse gradient was recorded
Number of roads without drainage channel in Awka	DRAIN	This number was identified and recorded
Number of flood channels blocked by houses and other civil constructions	HOUS	The identified number of civil structures on the channels were recorded
The average slope of the built up area of the town	SLOP	This was calculated from the topographical map of the area and recorded
The number of urban pavements constructed within the period of Data collection	PAVE	This number was determined and recorded
Number of natural flood channels identified in the town	WATU	The number of natural flood channels were identified in the town was recorded

Table 1. Contd.

The number of Housing estates in the town	ESTA	This number was determined and recorded
Whether or not the Houses are built on sloppy land	BUIT	If the Houses were built on sloppy land, we record 1, but if not zero (0)
Number of swamp sites which have been reclaimed since 10 years	SITES	The identified number of swamp sites that were reclaimed in the last 10 years were recorded
Number of flood channels blocked by sand since 10 years	SAND	The number of flood channels blocked by sand since 10 years was recorded
Whether or not there are settlements on the identified troughs	SETT	If there are settlements in identified troughs (1) is recorded when there are no settlement on the trough (0) was recorded
Temperature	TEMP	The average temperature of the town for 10 years was calculated and recorded
Rainfall	RAIN	The average rainfall for the 10 years period was calculated and recorded

Source: Fieldwork, 2010.

Table 2. Individual contributions of independent variables in the volume of flood in the entire Awka town.

Independent variables		Standard error of Estimates	R^2	R^2 (%)	Signs	F-Statistics
X_1	TEMP	0.091	0.166	16.6	+	32.613
X_2	RAIN	0.44	0.171	17.1	+	76.114
X_3	REFU	0.007	0.019	1.9	+	4.846
X_4	GRAD	0.086	0.113	11.3	+	7.648
X_5	DRAI	0.151	0.030	3.0	+	0.029
X_6	HOUS	18.964	0.003	0.3	+	0.138
X_7	SLOP	4.322	0.022	2.2	+	2.448
X_8	PAVE	0.096	0.069	6.9	+	5.208
X_9	NATU	0.425	0.001	0.1	-	32.661
X_{10}	ESTA	4.288	0.000	0.0	+	9.049
X_{11}	BUIT	1.336	0.001	0.1	+	65.207
X_{12}	SITE	5.466	0.002	0.2	+	2.840
X_{13}	SAND	0.006	0.003	0.3	+	3.088
X_{14}	SETT	2.672	0.000	0.0	-	2.482

Source: Fieldwork, 2010.

the 10 year period (2000 to 2009) and the result is presented in Table 3.

RESULTS AND DISCUSSION

The result of the analysis in Table 2 shows that the two climatic variables TEMP (average temperature of the area) and RAIN (average amount of rainfall) contribute a total of 33.7% of the variations to flooding while environmental factors contribute 26.3%.

Out of this 26.3% contributed by environmental factors, only five variables out of twelve namely; GRAD (number of flood channels with reverse gradient) with 11.3%; PAVE (number of urban pavements constructed within the period) with 6.9%; DRAIN (number of roads without drainage channels) with 3.0%; SLOP (average slope of land in built up areas of the town) with 2.2% and REFU (number of flood channels used for dumping refuse) with 1.9%, contributed meaningfully to the observed variation in flooding. These leave the remaining seven variables with the contribution of only 1.0%. Altogether, the 14 variables (climatic elements and environmental factors) contributed 60% of the variation in flooding in Awka town. It could also be seen that 12 of the variables carried positive signs while only 2 have negative signs attached to them. The standard error of estimates of the multiple regression is also shown in the table against each variable.

Furthermore in Table 3, it could also be seen that the multiple regression model produced results for climatic elements and environmental factors for each year of the analysis. Climatic elements contributed highest in four years: 2002, 2004, 2006 and 2009, while the environmental

Table 3. Summary of the relative contributions of climatic elements and environmental factors influencing flooding in Awka town (2000-2009).

Year	Contributions of climatic elements R^2 (%)	Contributions of environmental factors R^2 (%)
2000	26.1	33.9
2001	28.9	31.1
2002	36.0	24.0
2003	29.6	30.4
2004	40.3	19.7
2005	29.9	30.01
2006	42.8	17.2
2007	29.2	30.9
2008	29.6	30.4
2009	44.3	15.7
Mean	33.7	26.3

Source: Fieldwork, 2010.

factors contributed highest in the years 2000, 2001, 2003, 2005, 2007 and 2008.

It could however, be seen that climatic elements were the greatest contributors of flooding in Awka town during the period 2000-2009. The details of this contribution will be discussed later. This finding is in agreement with Agrail (2005) that climatic factors especially rainfall is the most important factor responsible for flooding in the urban areas of most tropical countries. The standard error of estimates of the multiple regression shown in column two indicates that the predictor variables with the highest standard errors are not good indicators of the volume of flooding in Awka town. In contrast, variables like TEMP, RAIN, GRAD, PAVE, DRAIN, SLOP and REFU have low standard errors of estimates indicating that they are fairly accurate estimators of the volume of flooding in Awka.

Also, 12 of the variables in Table 2 have positive signs showing that there is a direct relationship between these predictor variables and flooding in Awka town. This means that a unit increase in any of the variables (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_{10}, X_{11}, X_{12} and X_{13}) will also lead to a unit increase in the amount of floods (Y) generated in the town. The remaining two variables (X_9 and X_{14}) have negative signs showing that there is an inverse relationship between these predictor variables and the amount of floods in Awka town. This simply means that any unit increase in any of these predictor variables will lead to a unit decrease in the amount of flooding. This result is, however, in line with natural occurrences as a unity increase in the number of natural flood channels identified in the town (X_9) will lead to the decrease in flooding.

In other words, this indicates that the presence of natural channels in the town will surely limit the incidence of flooding in the town. The findings of Ebro (2010) in Kampala, Uganda supported this result when he noted that the consumption of 1 hectare of land by urbanization led to a 3 fold increase in flooding in Southern Kampala. Again, the variable (X_{14}) whether or not, there are settlements in urban troughs and lowlands is associated with inverse relationship with flooding. This is so because it is possible that most settlements located in such areas are provided with good drainage channels.

Furthermore, we had earlier stated in Table 3, were the multiple regression analysis result of the contributions of climatic elements and environmental factors are presented that climatic elements contributed higher in 4 years. One significant thing about this contribution is that it kept increasing every year. Thus, the years when it contributed higher than the environmental factors, these continuous increases are evident. For example, in 2002 it was 32.8%, in 2004 it was 34.3%, in 2006 it was 36.6% and in 2009 it was 44.3%. What this indicates is that the effect of climatic elements on flooding in the area is increasing every year most likely because of climate change. With this trend, in the next few years, the climatic element may contribute over 50% of urban flooding in Awka town.

Conversely, the years when the environmental factors contributed highest, it does not show the kind of increase observed with that of the climatic elements as there are fluctuations in the percentage contribution in various years. Altogether, the 60% contributions of both the climatic elements and the environmental factors show that 40% of the causes of flooding in Awka town are attributed to other causes, which could be traced to poor flood management, poor urban governance and improper planning of our urban areas.

Policy and planning implications

The issue of flooding has been one of the severest urban problems in Awka town. In 2008, the State Government approved and expended the sum of ₦133 Million for the channelization of Iyiagu flood problem (Anambra State Government, 2009). This measure has not addressed the problem of flooding in the town as virtually all the major roads are flood channels during any major flood occurrence. The flood problem in the second half of Arthur Eze Avenue towards the Expressway and that of the Post office area along Zik's Avenue is particularly worrisome. The policy and planning implications of this study is that the only measure that can solve this problem is the wholistic assessment of the entire city with a view to evolving a new master plan for urban drainage of the town.

The present piecemeal and partial planning of the flood programme in the town like the Iyiagu channelization programme earlier mentioned will not solve much problem. Presently, the master plan for the city prepared by the UN Habitat Kenya, made some provisions for addressing the problem but who knows when the government will begin to implement the plan. Even the plan document as beautiful as it may look, might not adequately solve the problem because of the poor local input into it. These issues are general to the problem, the following suggests specific measures to be undertaken, based on our findings.

Ensuring the use of climatic factors in the drainage master plan of the town

The findings in this paper clearly show that the climatic factors of rainfall and temperature are very important to the generation of flood in Awka town. Failure of the planners to recognize these vital factors will mean that the solution to the problem is not presently in sight. Muoghalu and Okonkwo (1998) suggested the incorporation of geographers, (mostly geomorphologists and meteorologists) engineers, geologist in the master planning team. According to them, only town planners and engineers are presently members of such team and they may not be able to handle the problem without the input of the other specialists mentioned.

Planning with relevant environmental factors

This study shows that it is not all environmental factors that contribute to the generation of flood in Awka. Out of the 12 environmental factors chosen, a number of flood channels with reverse gradient and the increasing rate at which pavements and concretes are being constructed in the urban area ranking highest with 11.3 and 6.9%, respectively. This particular factor should be looked at very seriously. Government should return to the old emphasis on open spaces, parks and grassy play grounds of the old. However, the construction of flood channels in the town has one basic problem which is reverse gradient, making it difficult for flood water to flow. Also, there are numerous roads without any form of flood channel instead of the gutters. This is the reason why whenever it rains, the road itself becomes a flood channel. Again, people should not be allowed to build in sloppy areas as the water that runs from their rooftops to the ground tend to accelerate very fast downhill sometime with destructive consequences. The issue of dumping refuse on flood channels needs to be addressed urgently. These factors should be seriously brought into the planning arrangement of government for the solution of flooding problems in the town.

Sensitization of the populace

The need to ensure that most environmental problems identified as important in the generation of flood are constantly put to check requiring that the populace should be constantly sensitized and educated. Considering the issue of blocking the flood channels with household and commercial refuse, government can pass information through local neighourhood leaders to solve this problem. This is the quickest and the surest way to get to the people at the grassroots. Again, government can use radio and other media outfits to get the message across to the populace.

Embarking on tree planting

This particular area needs to be seriously emphasized. This is because presently the few available trees have been cut down in the urban area mostly to give way to housing estates, roads and other human activities. Trees should be planted at the open places especially in the urban fringes where urbanization is still passive so that by the time urbanization gets to such area, they will no longer suffer the flooding problems of the urban core. In some of our old cities like Kaduna, Enugu, Kano and most northern cities, the planting of trees especially along the major streets was emphasized for the protection of the environment which includes the stopping of incidence of flooding.

Clearing the flood channels

One of the serious environmental factors generating flood in urban areas is the problem of the blockage of the flood channels. Apart from the dumping of refuse which we have been identified, the issue of the blockage of the channels by sand eroded from higher elevation areas and deposited in areas where the velocity of the flood could not carry them continues to be a recurrent problem. Government should come out with a law that makes it mandatory for all residents and shop owners to clear the gutter in front of their houses or shops so as to remove the sand and items that usually block it. The law should put stiff sanctions for all offenders.

Conclusion

We have tried in this paper to determine the relative contributions of climatic elements and environmental factors determining urban flooding in Awka town. It was seen that climatic elements contributed 33.7% out of the 60.0% generated by climatic and environmental factors. This shows that climate change may have had some serious adverse effects on the weather elements in the town. The need to isolate relevant factors and use them in the planning of urban drainage master plan needs no additional elaboration.

We have also seen that environmental factors cannot be ignored in such plan because of the contributions of such factors for urban flooding. The policy and planning implications however include the need to use relevant climate data in the planning of the towns' storm drains using relevant environmental factors in such plan, sensitization of the populace on the need to embark on measures that would reduce urban flooding, embarking on tree planting and clearing of the flood channels. There is need for government and other concerned bodies to employ our findings in this paper to reduce urban flooding in various urban areas so as to scale down the losses associated with it. Also, we need to be reminded of the fragile nature of our urban environment and as such require our protection to ensure its sustainability. This particular action is needed now than ever if we hope to achieve goal 7 of the MDGs which is ensuring environmental sustainability by the year 2015.

REFERENCES

Abaje I, Giwa PN (2008). Urban Flooding and Environmental Safety: A case study of Kafanchan Town in Kaduna State. In Mamman A. et al (eds.). Urbanization, Resource Exploitation and Environmental Stability in Nigeria. Joyce Publishers, Kaduna. pp. 64-81.

Agrail FD (2009). Rainfall and its Effects in Urban Environment. J. Atmos. Sci. 13(2):22-30.

Anambra State Government (2009). Iyiagu Channelization Programme Mimeographed.

Anyadike RNC (2009). Statistical Methods for Social and Environmental Sciences, Spectrum Publishers, Ibadan. p. 125.

Ebro E (2010). Kampala's Urban Problems. Sub-Sahara 3(2):6-13.

Eze BE (2008). Topography and Urban Expansion as Twin Factors of Street Flooding in Calabar Municipality, Cross River State in Bisong F. E. (ed.). Geography and the Millennium Development Goals. Translating Vision to Reality in Nigeria. Proceedings of the 50th Conference of Association of Nigerian Geographers (ANG), Index Book Publishers Ltd., Calabar. pp. 185-193.

Geoffrey L (2001). "Time Series" Analysis of Flood Events in Lagos, Nigeria. J. Hydrol. Afr. 8(2):20-32.

Goudie K (1981). Urban Planning in Developing Countries. Carlborne Press, New York.

Gray C (2005). Climatic Factors in the Generation of Urban Floods in Selected Sub-Sahara African Cities. Urbanization 2(2):112-121.

IPCC (1990). Climatic Change: The IPCC Scientific Assessment.

Mike JJ, Onell DB (2009). Analysis of relevant climatic elements in the study of urban flooding in Awka town, Nigeria. Clim. Environ. 5(2): 330-341.

Muoghalu LN, Okonkwo AO (1998). Effects of Urban Flooding in Awka, Capital of Anambra State, Nigeria. Environ. Rev. 2:22.

NPC (2006). The Population of Nigeria. Federal Government Gazette Vol. 96, No. 2, Government Printer, Abuja.

Obote JJ (2005). Flooding in our Cities: The case of Kampala. J. Afr. Dev. 8(2):60-69.

Odemerho FO (1993). Flood Control Failures in a Third World City: Benin City, Nigeria - Some Experimental Factors and Policy Issues. Geojournal 29:371-376.

Odemerho FO (2005). Benin City: "A case study of Urban Flood Problems'. In Onokerhoraye AG and Onita GEK (eds.). Perspectives on Development. Centre for Population and Environment.

Offiong RA, Eni DA (2007): Urban Floods: An Appraisal of the Effect of Flooding on Urban Infrastructure in Calabar Metropolis, Cross River State, Nigeria in Mamman A. B. et al (eds.). Urbanization, Resource Exploitation and Environmental Stability in Nigeria. Joyce Publishers, Kaduna. pp.75-91.

Okoro L, Basil MO (2012). A survey of environmental issues in the flooding of Awka urban. J. Environ. Anal. 3(1):15-24.

Onokerhoraye AG (1995). Benin: An African City in Transition,The Benin Social Sciences Series for Africa.

Sadat AJ (2009). Rainfall intensity and Duration as Two Factors of Flooding in Humid Tropics. J. Atmos. Sci. 13(2):10-16.

Sithole MA (2009). African Cities and their Environmental Problems. Nalsonel Press, Cape Town.

Slamaker BL (2000). Urban Development and Problems of Flooding in Nairobi. J. Urban Aff. 6(1):1110-1119.

Smith RA (1999) Effects of Urban Floods in Sub-Saharan African. Balico Press, Cairo.

Sule RO (2004). Environmental Consequences of Rapid Urbanization in Countries of the Developing World, Thumbprints International Company, Calabar.