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Flood risk assessment of river Mada: A case study of Akwanga local government area of Nasarawa state, Nigeria

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ABSTRACT

Flood is one of the malevolent effects on the environment which affects man adversely hence needs to be monitored and managed in order to avoid loss of lives and property. The assessment of flood risk in Akwanga Local Government Area of Nasarawa State was carried out using rainfall data and the perception of the floodplain dwellers. This study tests a central hypothesis that the flooding in the study area is dependent on the prevailing climatic element especially rainfall using Pearson product moment correlation coefficient. The rainfall variability and trend were analyzed using standard anomaly index and simple linear regression respectively. However, the study reveals that the possibility of flooding is to an extent influenced by the pattern of rainfall which shows a characteristic increase as the year progresses. About 250 questionnaires were administered to landowners in the selected settlements in the study area using systematic random sampling. The results of analysis showed, among other things, that the populations with regards to the settlement pattern are the most important causes of floods as well as heavy, prolonged rainfall which lead to river overflow, flooding. Nevertheless, they have little knowledge of the frequency of severe floods, and flood alleviation schemes. Most flood victims do not get compensation or relief during flood disaster. Finally, the study concludes that flood control in the region needs the cooperation of government, community efforts and an enlightenment programmes through environmental education and mass media.

Key words; Flood risk, rainfall, floodplain dwellers, environment, overflow.

INTRODUCTION

Flood remains one of the major causes of natural disasters affecting societies. Flood has been ranked “first” out of sixteen natural disaster type responsible for either one million dollars damages or injuries [1] after a study of the major natural hazards on world wide scale over a period of 1947 to 1967. The 1969 flood accounted for about 30% of all natural disasters and 45% of all fatalities [1].

Since man is unable to control the basic atmospheric processes which produce most floods, he has attempted to adjust to the hazard by means of flood alleviation projects concerned with land-based phase of the hydrological cycle [2]. In industrialized countries, the loss of life is usually lower because of flood control structures, zoning regulations that prevent the habitation of seriously vulnerable lands and emergency preparedness. To exemplify this, the case of USA deserves special attention if only to highlight that the low number of death (292) in the mid 90s, was not as a result of mild storm, snowstorms, little flood or weak hurricane and tornadoes but to the efficacy and high level of sophistication of EARLY WARNING SYSTEM (EWS) and the accuracy of the NOW-CASTING techniques which connect over 1000 RADAR network. Hence it has been identified that in terms of averting death, the United State of America is far ahead of the whole world in EWS and public enlightenment/sensitization campaigns on extreme weather events [3].

It is stated that through the application of high technology and the massive capital investments, flood threats to human lives has decreased appreciably in most developed countries within the recent decades [4]. Therefore, it was estimated that annual deaths resulting from flooding in the USA averaged more than 185 during the period 1831 to 1940 [5]. In the same vein, it was indicated that fatalities were reduced to less than 83 per year between 1925 and 1971 [6]. It has been observed that the improvement has been achieved largely as a result of better flood and hurricane warning measures which have permitted the temporary evacuation from hazard areas [2].

Irrespective of these achievements, property damage and disruption of life takes a great toll and despite flood control structures and land use planning, flood still do occur. It appears that the advanced countries are actually becoming more vulnerable to the loss of property and the social disruption associated with floods [2]. In less developed countries, humans are particularly the vulnerable flood causalities because of high population density, absence of zoning regulation, lack of flood control, high level of poverty, lack of technological know- how on flood management such as emergency response and early warning system. Nigeria is most vulnerable to impact or effect of climatic change and consequently flooding because of geographical location (4° and 14° North of the equator bounded in the north by the Sahara desert and the south by the Atlantic ocean). Thus it is indicated that "… without implementation of the protocols of the United Nation Framework Convention on Climatic Change (UNFCCC) through strategic programmes, Nigeria will be adversely affected by severe weather event including flooding and erosion…" [3]. Despite considerable investment in schemes designed to reduce the flood problem, mean annual losses have continue to rise [2]. In reference to the 1999 report on flooding, the flooding of Bakolori Dam area (defunct Sokoto State in Nigeria) in 1981, 1985 and 1995 calls for serious attention, for there were at least 65 deaths, over 12 billion hectares of farmlands washed away resulting in estimated farm produce loss of 100 million tons [3]. Infrastructural facilities (houses, roads, schools etc) that were destroyed cost over 50 billion Naira. However, floods so far experienced may be mild in comparison with speculated trends which suggest the sea level rise and severe storm in Nigeria may be more devastating in future. From the foregoing, it is evident that an assessment of the flooding events and forestalling processes of the country is required in order to proffer reliable suggestions, solutions and policy framework aimed at the reduction of flood damages.

In order to assess the flood risk of the area under study as well as proffer efficient solution to the flood dangers, the following questions need to be answered;

- What are the causative agents of floods in the study area?
- To what extent do climatic factors influence the incidence of flooding phenomena in Mada area?
- What method can be used in the assessment of flood risk in study area?

The research on the flood risk assessment of Mada River is aimed at generating data on the nature of behavioral responses of the floodplain dwellers to the risk of flooding which will help policy planners in development of the floodplain and reducing the large scale damage and losses that may arise from flooding in the study area. Also the research is aimed at analyzing the nature of floods and their relationship with climatic changes.

To realize this aim, the following specific objectives were addressed;

- An analysis of flood generating mechanism in the study area from the climatological perspective with a view to predicting flood occurrences.
- An analysis of the behavioral responses of the floodplain dwellers to the risk of flooding; and
- An investigation of possible risk management strategies for the study area.

Study Area: Akwanga Local Government Area is one of the thirteen Local Government Areas of Nasarawa State located within latitude 8°5' and 9°0' North of the equator and between longitude 8°15' to 8°30' East of the meridian with a point location of 8°55',8°25'E [7]. The Local Government Area is bounded in the north by Sanga Local Government of Kaduna State, Nassarawa Eggon in the south, and Wamba in the East and lastly Kokona in the West.

Geology, topography and drainage

Geologically, Akwanga Local Government Area is part of the Precambrian aged basement complex rock which covers about 60% of the total superficial area of Nasarawa state. The study area is also composed of granite which intrudes the basement complex at Mada and Afu and therefore do not occupy any separate landmass of their own.

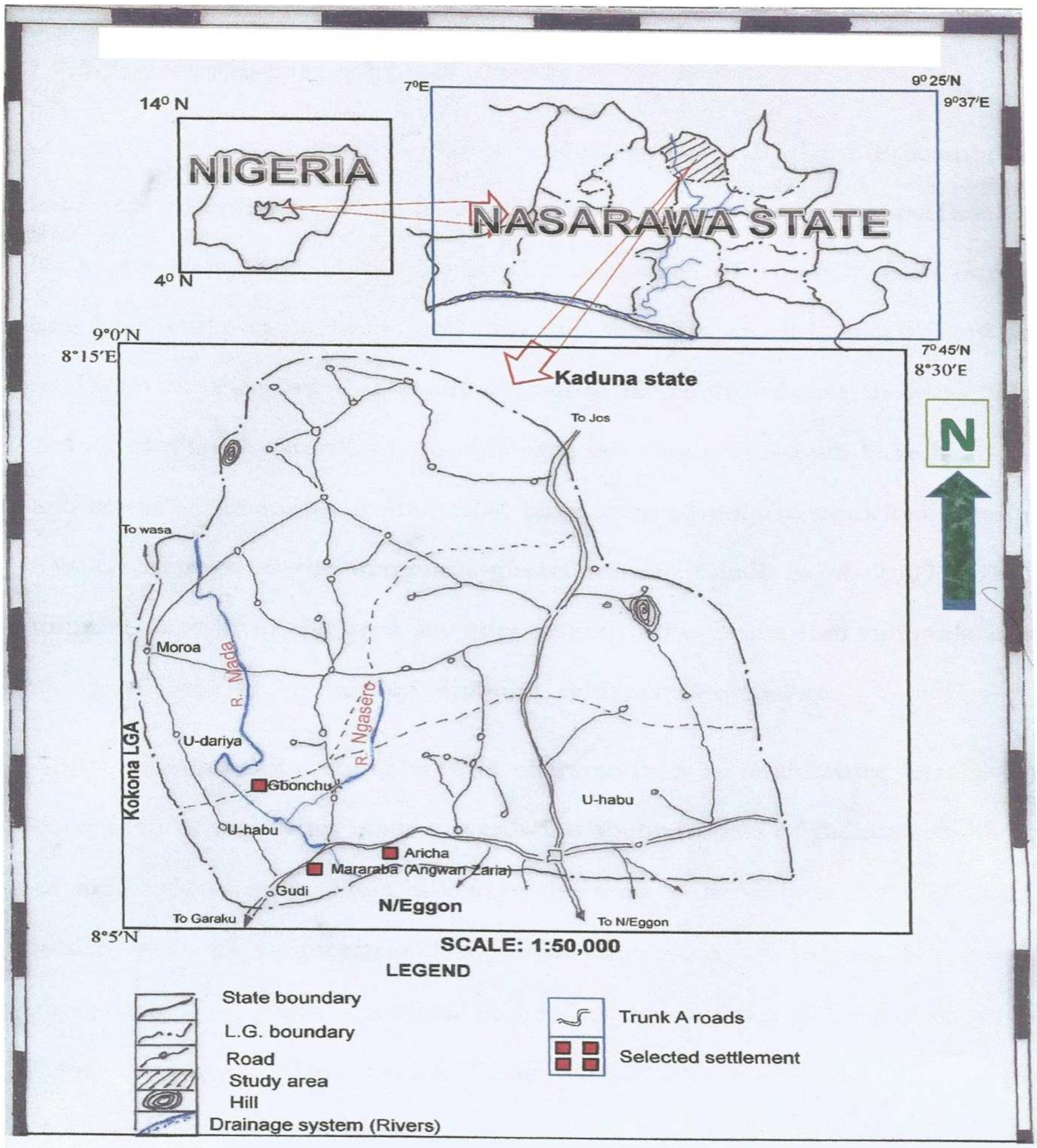

Fig: 1.1 MAP OF NASARAWA STATE SHOWING THE STUDY AREA

The older granite is mainly biotite granites. North of Akwanga, a large outcrop of granodiorites trending north-south have been mapped; and south of Akwanga around Ube, large crop of dolorites/diorites trending NE-SW crosscut the large magmatic-gneiss terrain [8]. The major mineral deposit in the area includes among others; uranium minerals occurring along Afu and Mada, thorium, niobium, feldspar and fluorspar.

Topographically, the study area is characterized by undulating terrain which is composed of low-lying lands towards the southern part of the area and a network of hills in the north. Thus, allowing the area to be drained by the Mada River which takes its source from Jos plateau and meanders through the interlocking dissection of the Jema'a platform and enters the state through the northern borders. Other drainage systems include; Rivers Kegin Daji, Katari, Ekoalio, Kyeruku and Azuta which are the tributaries of River Mada.

Climate
The climate of the study area is similar to that of the State except for micro variation caused by terrain morphology. The temperature increases from January to March where it reaches a maximum of about 39°C with the unset of the month of April, temperature decline notably to a minimum of about 17°C by December.

The relative humidity thus is as low as <40% in January and as high as 88% in July (during the wet season) [9]. About ninety (90%) percent of the rain falls between May and September, the wettest month being July and August. The rain comes with thunderstorm of high intensity particularly at the beginning and the end of the wet season.

MATERIALS AND METHODS

Research design
Data of flood risk assessment was collected through the secondary and primary methods.
Data; type, nature and sources
The major forms of data collected are primary and secondary sources of data. The primary data include data on behavioral response especially the perception and adjustment of the floodplain dwellers to the risk of flooding. This information will be acquired through;

Primary Methods:
Direct field observation
Field observation was also carried out with a view to knowing the general conditions of the study area. Measurement of the length and thickness of the floodplain was done for easy comparison with the depth of floodwater acquired through the questionnaire.

Questionnaires
A total of 250 questionnaires were distributed among the settlements along floodplain of River Mada using systematic random sampling technique. Sampling of building in each settlement depends on the population of the buildings.

Questions were asked on the biodata of the floodplain dwellers, their perception of the hazard at the time of interview and the nature of adjustment made either in anticipation of flood or during flood. Other questions asked include; those of flood magnitude and the risk of future floods in order to gain an insight to their level of perception as at the time of interview.

Interview/group discussion
Group discussion with the floodplain dwellers was further used in order to obtain detail information on the flooding activities and also to annul any inherent error or misinformation that may exist in the data acquired with the questionnaires. In this activity (group discussion), respondents with similar age, sex and educational qualifications were interviewed at the same time so as to unify the information being acquired.

Secondary Method:
The secondary data on the other hand included mothly and annual rainfall data obtained from the Department of Meteorological Services, Nigerian Meteorological Agency, Lafia, Nasarawa State. The rainfall data covered 12 years period from 1997-2008.

Sampling technique
Systematic Radom sampling technique was used in the administration of the questionnaire. This is a technique where every particular n^{th} term in an observation is sampled. However, three settlements along the floodplain were selected; they are Mararaba, Gbonchu and Aricha. Moreover, every third house in the sampling frame has an equal chance of being selected.

Method of data analysis
Two major techniques were employed in this research. They are;

Meteorological technique

This technique was adopted as described by Ologunorisa [2] in order to analyze and describe the rainfall characteristics in the study area. In the preliminary treatment of the data, basic statistical tools such as computation of totals, means and standard deviation were employed for the analysis of rainfall data in the station. The analytical techniques employed include Pearson product moment, correlation coefficient and student t-test in order to test the hypothesis, simple linear regression analysis for determining the trend of rainfall and standard rainfall anomaly index in obtaining the variability in the annual rainfall.

Pearson product moment correlation coefficient

This statistical technique is used to correlate mean annual rainfall with time. It is defined as a scaled index which measures the effect or paired variation between two continuous variables [2]. This technique was used because the degree of association between rainfall and time were examined. Also because it is parametric, it is far more superior in terms of its efficiency is more than its non-parametric equivalent, spearman rank correlation. The formula is given as follows:

$$r = \frac{\left[\frac{1}{n}\sum(x-\overline{x})(y-\overline{y})\right]}{\delta x \delta y}$$

Where r = Pearson product moment correlation coefficient

$\overline{x}$ = mean of rainfall values

$\overline{y}$ = mean of time values

n = number of sample size

δx = standard deviation of rainfall (x variable)

δy = standard deviation of time (y variable)

The 'r' gives information on the direction and strength of the trend. To test whether the correlation coefficient obtained is significant or not, Student 't' test which is a test for significance was employed. The formula is given as follows;

$$t = {}^{r}\sqrt{\frac{n-2}{1-r^2}}$$

Where t= student test
r = correlation coefficient
n = sample size
r^2 = coefficient of determination.

Simple linear regression analysis

Simple linear regression analysis is the second technique used for determining trends in this study. The formula is;

$$y = a + bx$$

Where $b = \frac{[\sum(x-\bar{x})(y-\bar{y})]}{\sum(x-\overline{x})^2}$

$$a = y - bx$$

Where a = the base intercept
b = the regression coefficient or slope
x = rainfall values
y = years

The advantage of this method is that it provides a unique solution to time series problem by identifying the underlying long-term linear trend [2]; it is also relatively simple in application.

Standard rainfall anomaly index

Rainfall data in study area was analyzed for variability using standardized rainfall anomaly index (SAI) which is the most commonly used index for regional climate change studies. Its value for the year j is given by;

$$X_j = \frac{(ri_j - ri)}{\delta_1}$$

Where $X_{j=}$ the normalized departure

ri_j = the annual rainfall for the station in the year j

ri= the long-term mean for the station i_j and

$\delta_{1=}$ the standard deviation of the station with annual rainfall.

Socio-economic technique

The reaction of the floodplain dwellers was analyzed using simple percentage techniques. The biodata of the respondent gives the information of how long the respondent might have lived in the area and their wealth of experience to flooding activity in the area.

Method of flood risk assessment

Six indices were utilized for measuring level of flood risk in the study area. These are identified as being capable of truly measuring flood risks [2]. Some scholars have shown that these indices have strong positive bearing on flood generating and vulnerability component of flood hazard [2]. The parameters selected are easy to measure and quantify as well as it is believed that they will clearly bring out internal variation within the study area.

Table 1: Graduated scale for scoring the selected parameter used in the defining flood risk

Parameter	Range value	Scores
	<1.0 meters	1
Depth of flooding (m)	1.2 meters	2
	>2.o meters	3
	<12 hours	1
Duration of flooding (time)	12-24hours	2
	>24 hours	3
	Once in 5 years or more	1
Perceived frequency of occurrence	Once in 3 years	2
	Once a year	3
	<25%	1
Extent of damage in percentage	25-50%	2
	>50%	3
	200 meters	1
Proximity to hazard source in meters	100-200 meters	2
	<100 meters	3
	Agricultural industrial	1
Dominant land use or economic	Planned and unplanned	2
	Industrial/commercial	3

Source: Field survey, 2009

RESULTS AND DISCUSSION

In assessing the flood risk of some areas around River Mada in Akwanga Local Government Area of Nasarawa State, rainfall data were analyzed using meteorological and statistical techniques such as Pearson product moment correction coefficient and simple linear regression analysis to acquire the rainfall trend and variability. The perception of floodplain dwellers were also analyzed using simple percentage.

Annual rainfall trend

Regression analysis is used to examine the rainfall trend in the study area with respect to time. This method was adopted after Ayoade and Ologunorisa [10,2]. The regression table below depicts a positive relationship. This means that as the year progresses, the annual rainfall of the study area was expected to increase in magnitude thereby increasing the possibilities of flooding in the area.

Table 2: Summary of regression analysis [11]

Rainfall (independent variable x)	Dependant variable y
1105.9	6.034
623.7	2.465
927.2	4.711
947.3	4.860
1347.5	7.822
1291.5	7.407
1416.8	8.334
1322.6	7.637
1284.7	7.357
1288.7	7.386
1507.1	9.003
968.7	5.018

Constant (a) = -2.15, Regression Slope (b) = 0.0074 , Regression equation = -2.15 + 0.0074x

Annual rainfall variability

The annual rainfall variability in Akwanga was analyzed using Standardized Rainfall Anomaly Index (Table 3). The result shows that rainfall varies from year to year with 1997, 1998, 1999, 2000 and 2008 falling below the average annual rainfall while 2001, 2002, 2003, 2004, 2005, 2006 and 2007 rising above the average annual rainfall. A sharp variation is thus noticed in 1998 (lowest) and 2007 (highest). This result tallies with that of the Niger delta area which indicates a comparatively increase in rainfall in the area [2].

Table 3: Summary of Standardized Rainfall Anomaly Index analysis (SAI) [11]

Year	Standardized rainfall index (SAI) value
1997	-0.26
1998	-2.22
1999	-0.99
2000	-0.90
2001	0.73
2002	0.50
2003	1.01
2004	0.62
2005	0.47
2006	0.49
2007	1.38
2008	-0.82

Public perception of flood hazard in River Mada

Land ownership result (Table 4) revealed that, about 60.8% of the respondents are the owners of the property they occupy, 35.2% are tenant while 4.0% have communal ownership.

Table 4: Land tenure system of the respondents

Tenure of house and land	Frequency	Percentage (%)
Owner	152	60.8
Tenant	88	35.2
Labourer		–
Communal	10	4.0
Total	250	100

Source: Field survey (2009)

This result implies that large amount of the respondents are owners of the property in the area of study and thus indicate to a certain extent the degree of stability and validity of the response as it is expected that the property owners have either been directly or indirectly affected by flooding events.

Duration of stay in areas round River Mada
However for the period of stay by each settlers, table 5 shows the years of stay by individual people.

Table 5: Duration of stay in areas round River Mada

Duration (years)	Frequency	Percentage
1-3	22	8.8
4-6	30	12.0
7-9	20	8.0
10-12	48	19.2
13 and above	114	45.6
No response	16	6.4
Total	250	100

Source: Field survey (2009)

The aforementioned table 5 reveals that more than half of the population (respondent) has lived in the area for a period up to 13 years. That is about 45.6% of the respondent had stayed to13 years and above, 19.2% for 10 to 12 years while 12%, 8.0% and 8.8% lived in the area where they were interviewed for a period of up to 4 to 6 years, 7 to 9 years and 1 to 3 years respectively. This shows a high rate or degree of stability which to an extent ensures validity in the information acquired.

Perceived flooding experience
In terms of the flooding experience in the area, about 90% of the respondent have experienced flood in the area of interview. This data was acquired in order to ensure that those interviewed have experienced flooding in the area and so have valid information on the perception of flood risk.

Discussion on the cause of flood in the area was left open (open ended question) in order to acquire the view of the respondent which will not be subjective. Opinions regarding the cause of flooding indicate a fairly wide variation in the respondent perception of the nature of the hazard. The data acquired shows that about 54.4% of the respondent opinions revealed that heavy and continuous rain to be the cause of flooding while 24.4% were of the opinion that flooding results from river overflow. About 11.2% viewed the cause of flooding to be the agricultural land use where cultivation of the river banks due to fertile soil and availability of water leads to the reduction of the width of the sediment. Other reasons such as drainage blockage and no response amounted to about 9%. This data thus shows the degree of awareness of the population to the effect of climatic variables to flooding hazard as well as their knowledge about the environment.

Information on the perceived period of flooding was also acquired. The table 6 below shows the result;

Table 6: Perceived period of flooding in river Mada

Period	Frequency	Percentage (%)
Jan-march	6	2.4
April- June	46	18.4
July-Sept	164	65.6
Oct-Dec	25	10.0
No response	9	3.6
Total	250	100

Source: Field survey (2009)

The above results in table 6 reveals that the months of July to September having a value of 65.6% could be regarded as flood season in the river Mada area. This period also coincides with the wet season in the area characterized by water surplus due to heavy rainfall of long duration.

Response on the perceived frequency of flooding showed that about 40.4% said 0 to 4 times a month while about 39.2% had no response to the question.

In terms of the loss of property due to flooding event, a very high degree of the respondent opinioned that the major losses are agricultural crops and farmland thus indicating the nature of their economy.

Spatial variation in the level of flooding in the study area
The assessing of flood risk in areas around river Mada was carried out based on some parameter listed in the previous paragraph. The result acquired is shown below.

Table 7: Computation of flood risk in River Mada (Akwanga)

S/N	Settlement	Perceived depth of flood (m)	Perceived duration of flood (time)	Perceived frequency of occurrence	Perceived extent of damage in percentage	Proximity to hazard source	Dominant land use or economy
1	Mararaba (Angwan Zaria)	2	2	3	1	1	1
2	Gbonchu	1	1	3	1	1	1
3	Aricha	1	2	2	1	1	1

Source: Field survey (2009)

The above result (Table 6) shows that there is a correlation in the economy, distance of the flood hazard source (River Mada) and extent of damage in the three settlements. This could be explained to be the resultant effect of the dominant ethnic group (the Mada people) and the settlement pattern which is nucleated in nature with little buildings scattered here and there. However, the settlement of Mararaba shows a higher flood risk with a perceived frequency of once a year and a perceived flood depth of about 1.2m. On the other hand, Arichi experiences flooding with similar depth as that of Gbonchu settlement but unlike the later, and has a longer perceived frequency of once in 3 years.

In order to achieve the insight to the nature of adjustment of flooding by the population, questions were asked on the availability of alleviation schemes. A high degree of the respondents (79.2%) are not aware of flood alleviation scheme and have helped in tackling effect of flooding through communal co-operation especially from family members.

Hypothesis testing
Pearson moment correlation coefficient was used to test the hypothesis of the research. Correction analysis, a method that have been used in several studies prominent scholars [2, 12] have been eulogised as an efficient technique for the investigation of trend exhibited by the phenomena. From the climatological point of view, trend is used to describe the general increase or decrease in climatic phenomena [2]. The table below shows the result obtained.

Table 7: A summary of correlation coefficient, coefficient of determination and significant at 95% level of confidence.

Correlation coefficient	Coefficient of determination	Student "t" value	Critical value	Result
0.53	**0.28**	**1.98**	**1.81**	**Significant**

Source: Field survey, 2009

It is evident from the table above that the calculated value of the test statistics is higher than the critical value determined before hand, thus, the Null hypothesis (Ho) will be rejected. On the other hand, the Alternative hypothesis (Hi) which states "There is a significant relationship between rainfall and flooding event in areas around River Mada" will be accepted.

The result however shows that there is an upward trend in rainfall which is statistically significant at 95% level of confidence. This is in complete agreement with findings in reports of flooding for Yenagoa and Ahoada in the Niger Delta area of Nigeria [2]. On the other hand 30 years data from 1931-1960 for 42 stations in Nigeria was used and only three (Onitsha, Abakaliki and Ikot-Ekpene) showed a positive trend [10]. However, this upward trend in the rainfall pattern of areas round River Mada is not random and shows a positive correlation which indicates upward annual rainfall trend and consequently higher possibility of flooding.

CONCLUSION

The research work reveals that the flooding of the localities under study is seasonally dependent with the wet season having most of the hazard episodes. Thus, with higher precipitation (rainfall), the volume of the water increases and

leads to the overflowing of the river banks. This is compounded by the terrain of the area where localities are at the river lower course.
The disruptions caused by flooding event cuts across the economy of the people through the frequent destruction of the agricultural produce, farmland and to an extent communication route as well as road network.

With the problem of global sea level rise due to melting of the polar icecaps as a result of global warming, the risk of flooding in floodplain will increase and if efficient and effective measures are not taken the destruction by flood will be catastrophic.

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