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Erosion and Flood Vulnerability of Soils: A Climatic Challenge in Southern Nigeria

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ABSTRACT

The soil erodebility and flood vulnerability of areas in the Southern Nigeria are studied using the climatic data for thirty six (36) years and fifteen soil/rock samples from erosion sites. The monthly mean rainfall and temperature data were subjected to linear regression and trend analysis. The result of the R^2 regression method shows that the rainfall for Ikeja, Ibadan, Ondo, and Oshogbo areas varies from 1.2% to 4.5% in an increasing trend, an indication that the rainfall is not uniform over the years even though the temperature under the same condition indicates a decreasing trend. Similarly, the rainfall for Enugu, Umuahia and Owerri areas ranges between 0.6% and 5.2% in an increasing trend with temperature varying from 22.5% to 31.3% in a decreasing trend as well. The results of the particle size analyses for the soil/rock samples from erosion sites show three classifications in the following ranges; gravel 0.9%-1.7%,medium sand 69.3%-87.0% and fine sand 11.3%-29.0% respectively. This type of soil compositions from fine to medium grained favour the insurgence of erosion and by extension flooding under a continuous increasing trend of rainfall. Government is advised to adopt a proper urban management planning to avert flooding and its attendant unpleasant disasters.

Keywords: *Soil, erodebility, flood vulnerability, particle size.*

1. INTRODUCTION

A climatological cycle of the total annual rainfall and temperature across Nigeria is believed to be regular in terms of wet and dry seasons in the 60s, 70s and parts of 80s from South to the North and to some extent from East to the West . The total annual rainfall then generally decreased from 4500mm in Bonny area to about 2500-3000mm in the Warri and Port Harcourt axis (Ogba *et al* ;2008) and from Calabar areas to between 1250mm and 2500mm in South west, with mean annual rainfall precipitation at Lagos and Ibadan at 1900mm and 1250mm respectively. Flooding and erosion occurred but on a less noticeable scale and extent. Flooding is a natural phenomenon that exists and will continue to occur as long as rain falls on the continent. The Southern Nigeria region comprises the South East, South West, and the South South geographical areas.

In the new millennium and over three decades now , flooding challenges have been of international, regional, national and community discourse (Panagonlia and Dimon,1997; Mimikon *et al*.,2000., Vorosmarty *et a.*, 2000; Simonovic and Li;2003; Lou, 2003; Yin, 2003; Barnette *et al.*, 2004; Dettinger *et a.,l* 2004) .Kron (2000) points out that no region of the world is safe from being flooded. In southern Nigeria, authors such as Odemerho,1988; Rashid, 1982 ; Zabbey,2006, and Andjelkovie 2006 worked on flooding, its prevention and remediation. It is also believed that climate change can lead to high floods in several regions of the worl (Muzik,2002,Wang, 2003)

Rainfall is one major climatic factor in the tropics among other factors of temperature, and wind that causes or precipitates the erodebility of soil and vulnerability of same to flooding. The regularity, intensity and amount of rainfall over time not only dislodge the soil particles by making them susceptible to erosion but also using the soil particles to seal the soil pores thereby reducing the water infiltration and increasing runoff and by extension flooding. Many authors believe that soil erosion can also be caused by other factors such as improper agricultural practice (FMANR, 1990) and anthropogenic activities in vulnerable areas (Ogba and Utang , 2008).

Rainfall and temperature are indirectly related to flooding and erosion. The duo data for thirty six years (36) (1971-2007) were collected from the Nigerian Meteorological Agency, Lagos and subjected to regression/trend analysis. Decadal approach of the analysis of the data was undertaken to ascertain if any increase or decrease or variation of the climatological cycle has occurred over time within the Southern parts of Nigeria. The problems of climate (rainfall and temperature) will continue to attract attention amongst scholars in the years ahead because of its central and natural existence. An integration of rainfall and geotexural characteristics of the soil as causatives of soil erosion and flooding are what the paper intends to study.

2. MATERIALS AND METHODS

Climatic data of rainfall and temperature for the selected locations in southern Nigeria for thirty six years (36) were collected from the Nigerian Meteorological Agency , Oshodi-Lagos. These data were grouped into decades in order to carry out a trend analysis of rainfall and temperature regimes. The monthly mean rainfall (R) and temperature (T) were computed from the monthly annual data and subjected to regression/ trend analysis. Simple linear regression method was used to analyse the trend in the time series of rainfall-temperature data. Fifteen (15) soil/rock samples were collected from the erosion sites around Ondo State and subjected to particle size analysis to determine the textural characteristics.

Geology and Location of study areas

The study areas covering the Southern Nigeria are represented by Owerri,(Imo State) Umuahia (Abia), Enugu, (Enugu State) Ikeja (Lagos State), Oshogbo (Osun State) and Akure (Ondo States) respectively. (Fig 1)

These areas are under the same hydro climatic and vegetative influence of the rain forest region of Nigeria characterized by heavy seasonal rainfall and high temperature throughout the year. Geologically, the rock systems and geological history of Umuahia, Owerri and Enugu spanned during the events that occurred between Mesozoic and Cenozoic eras during which the upper coal measures, false-bedded sandstone and lower coal measures formed (Nwilo, 2011). The sedimentary rocks of these areas comprise Cretaceous sediments which are the Nkporo shale Formation, the Mamu Formation (Lower Maastrichtian) , the Ajali Sandstone (Upper Maastrichtian) and the Nsukka Formation. Most areas of Southeastern Nigeria are made of moderate to gently dipping, poorly consolidated sandstone that are associated with regional highlands of Udi- Okigwe and Orlu and Ohafia- Arochukwu. These highlands are formed by sandstone bedrocks of Ajali sandstone and Nanka sand (Eocene) while their lower slopes and plains are underlain by shaly units of Imo, Mamu,Nsukka and Bende Ameki Formations. (Enuvie ***et al***; 2010) .The Ajali sandstone which overlies the Mamu Formation consists of friable poorly sorted highly cross-bedded sandstone. The Ajali sandstone is overlain by lateritic red earth deposits in most areas of the South Eastern Nigeria. (Ezeigbo,1993).

3. RESULT AND DISCUSSION

Table 1shows the data on monthly mean rainfall for Ondo,Lagos, Ibadan and Oshogbo for thirty six (36) years. The mean monthly rainfall for Oshogbo ranges between 5.55mm (Dec) and 213.33mm (Sept) , for Ondo it is 5.77mm (Jan) and 243.28mm (Sept) , 5.10mm (Jan) and 184.55mm (Sept) for Ibadan, and 14.07mm (Jan) and 193.64mm (Sept) for Lagos respectively

Table1 generally shows there was rainfall throughout the year in every month with rainfall peaks in June and September and a break called “August break” in august. This Scenario shows a climatological compliance in the wet and dry season cycle of Nigeria. The data also show that over 200mm of rain occurred in June in both Ondo and Ikeja areas marking the flood periods of the year. The Southern Nigeria comprises the South East, South West, and the South South geopolitical regions of Nigeria.

Table 2 shows the monthly mean rainfall for Owerri, Enugu and Umuahia. The data display two rainfall maxima June and September for Owerri, one peak each of June and September for Umuahia and Enugu respectively. The data show a significant increase of rainfall from January to November in Owerri whereas Enugu has the least of the rains from November through March.

Table 3 shows the trend and regression values for the rainfall data generated from the Microsoft Excel computations .The World Almanac and book of (WABF) suggests that the least square regression (r^2) calculates the best fitting line for any observed data by minimizing the sum of the squares of the vertical deviation from each data point to the line. The r^2 values indicate the degree of variation in percentage. Based on this the variation of rainfall in the locations in Table1 varies from 1.2 % in Ikeja to 4.5% in Oshogbo, an indication that the rainfalls over the thirty years are not uniform even though the trend indicates an increase (Fig 2

Similarly, the square regression values ($r^{2)}$ for Owerri, Enugu and Umuahia show that the rainfall varies from 0.6 % to 5.2 %. with an increase in the trend of occurrence. (Table 4, Fig3It is observed that whereas the trend of rainfall shows an increase over the years ,the temperature indicates a wide variation with a decreasing trend in all the locations under study. (Tables 5) These data reveal that the southern divide of Nigeria has an increasing amount of annual mean rainfall over the years with decreasing trend in temperature .The variations establish the fact of the existence and prevalence of the climatological cycle of rainfall and temperature with the attendant rainfall increases that cause flooding.

Soil erodebility and flooding

Soil gully erosion cannot occur in isolation of running water effect occasioned by high intensity continuous heavy downpours especially in the southern parts of Nigeria. Nwilo (2011) is of the opinion that 45% of the Eastern Nigeria, (Anambra Enugu, Umuahia and Owerri inclusive), are affected by measurable erosion and that about 20% of the land surface suffers from severe sheet erosion. Ogba and Utang (2008) state that in the Niger Delta coast, flat topography dissected by a plethora of river distributaries and their associated plains with high but spatially variable rainfall make the areas vulnerable to flooding. Agreed that heavy rainfall has adverse impacts on landforms and landscapes, the soil/rocks textures also can make the latter vulnerable to flooding .

Rainfall and Geotexural influences

Rainfall is one prime climatic factor, variable, active, destructive and pivotal to a conglomerate of actions on environmental soil problems and flooding . Fig 4 shows the various roles of rainfall in accelerating flooding and erosion in the southern part of Nigeria.

Temperature and water affect weathering-. Lithified/consolidated land surfaces under constant raindrops and alternate high temperature undergo exfoliation and weathering. An unconsolidated land surfaces either due to natural processes or human land use absorb water readily and get saturated. When the absorption capacity of the soil is exceeded by the infiltrating water, runoffs occur and subsequently flooding results. Significant flooding and erosion events have taken place in many parts of the southern Nigeria. Erosion devastates any surface that is unconsolidated, friable, sandy or silty like the sandstones of the Ajali Formation and the Nanka sands that underlie most parts of Anambra, Enugu, Imo and Umuahia areas. Some areas that are underlain by the shale units of the Mamu and Nsukka formations are less susceptible and vulnerable to serious erosion. However, repeated absorption of water and shrinkage will weaken the soil/rock surfaces thereby making it susceptible to erosion .

A particle size analysis of the soil surfaces taken from erosion sites of some parts of Ondo State (Plate 1) shows the predominance of sand and gravely components (Fig 5-6).

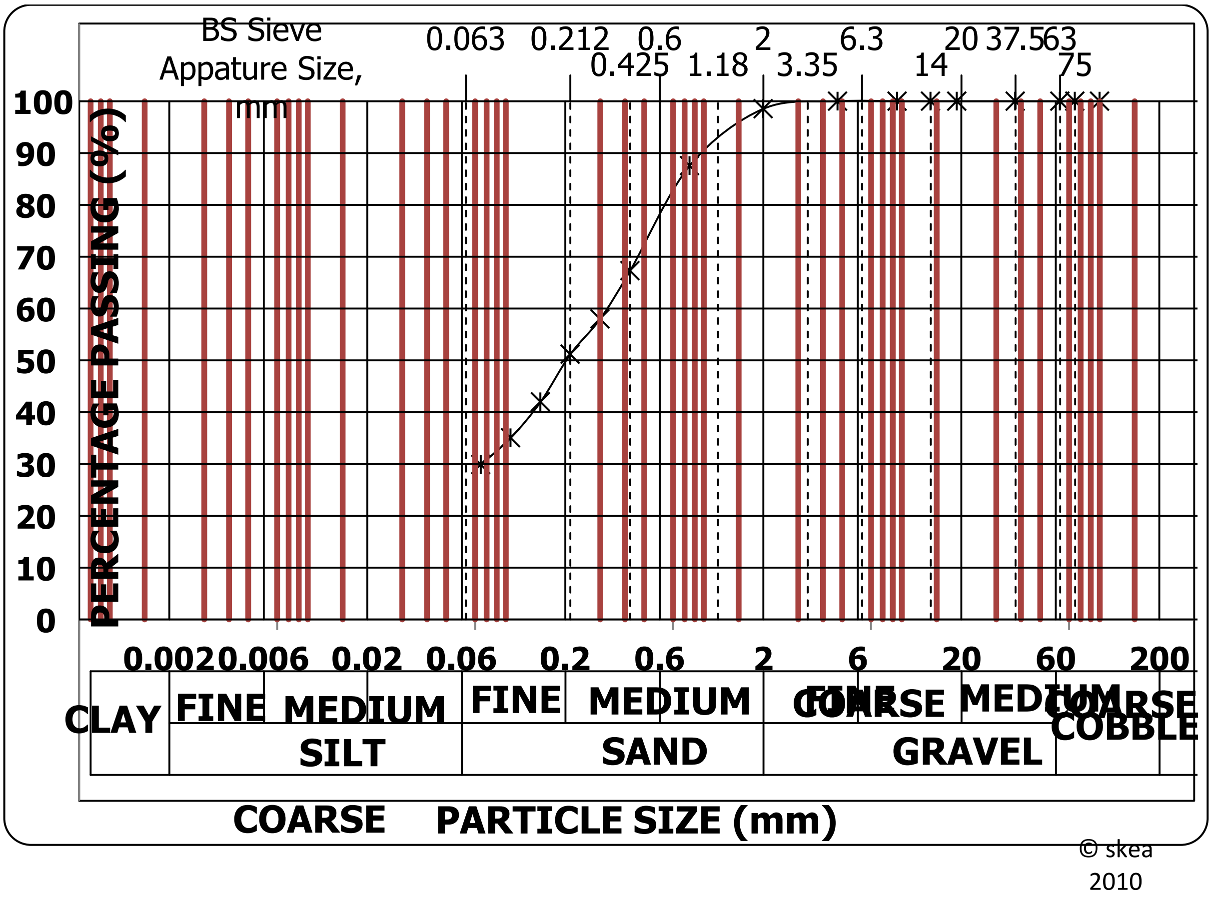

Fig. 5 Particle size of an erosion site at Okitipupa area of Ondo State.

Table 6 indicates the results of particle size analyses of parts of erosion sites within Ondo State . The results show that the percentage of sand composition ranges between 71% and 85% whereas the gravel varies from 1.1% to 1.7% , an indication that the areas are predominantly sandy and are therefore vulnerable to erosion and flooding.Sandy environment is vulnerable to erosion. It easily absorbs water and get saturated in which case the water that can no longer be absorbed runs as runoff. Concentrations of accumulated runoff flow on the surface as flooding washing away landforms and submerging property and infrastructures it gets into on its way.

Lagos, Edo, Anambra, Ibadan, delta, Ondo and other areas along the coasts of River Niger and its distributaries have witnessed an unprecedented flooding since the beginning of August 2012 . The outburst of rain that constituted these flood hazards is an evidence of variations which hitherto agrees with the analysed increased rainfall trend. Government officials have advanced reasons for the flooding to heavy rainfall and the release of water from the dams in the surrounding countries of Nigeria. Obasi and Ikubuwaje (2012) are of the opinion that in the Nigerian context the unusual , destructive and submerging attitudes of heavy downpours in the present decade are emerging evidences of climate change in the localities.

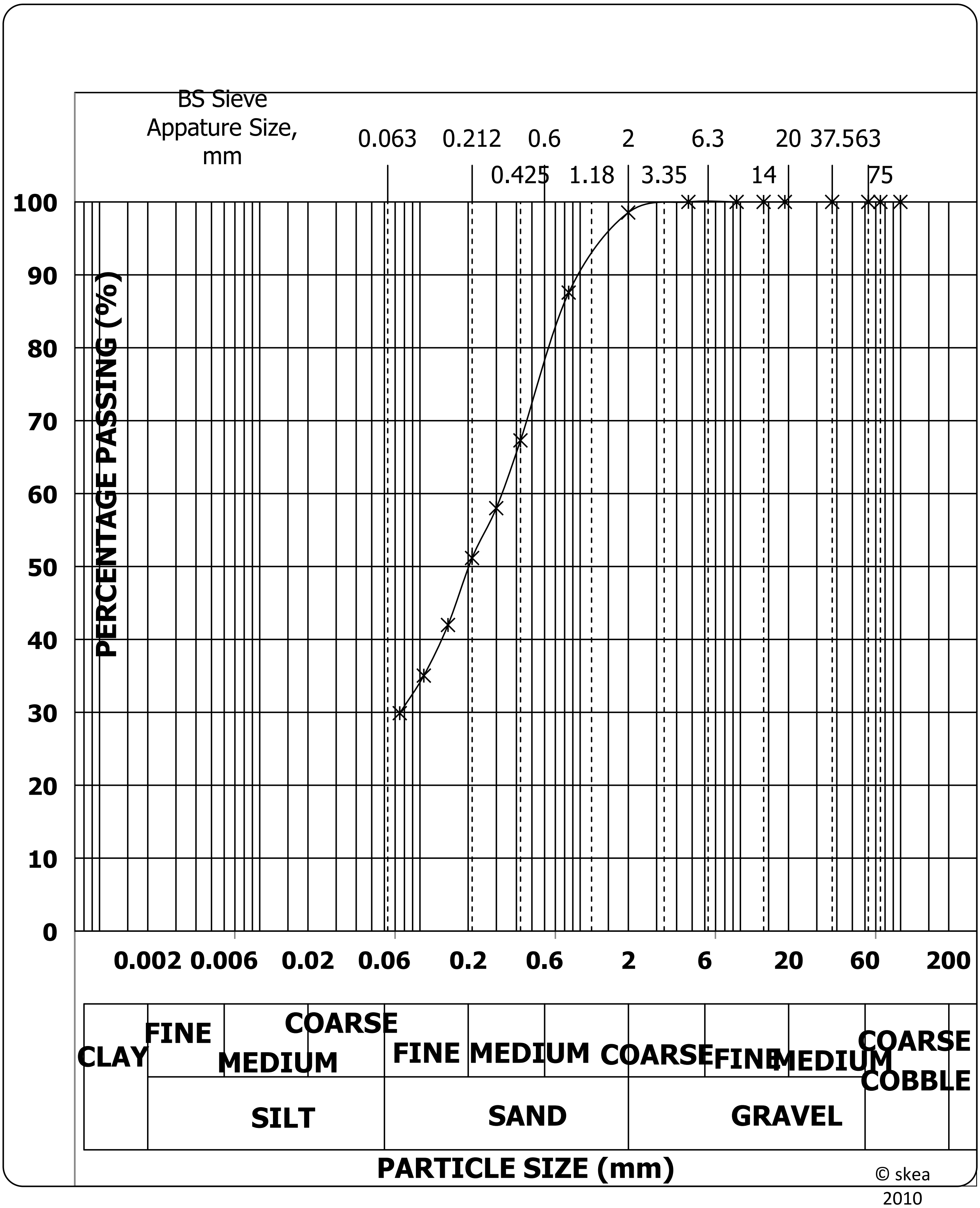

Fig 6: Particle size analysis of an erosion site at Okitipupa area.

4. CONCLUSION

The erodebility of a soil /rock is a function of factors such as soil textures, rainfall and human activities on landforms as well as government attitudes to proper urban planning. An analysis of climatic data for thirty six (36) years (1971-2007) for the areas in the southern divide of Nigeria was undertaken. The result shows that the climatic cycle of wet and dry seasons prevalent in the 60s, 70s, and 80s still occurs in spite of variations that occur in the intensity, amount, and trend of rainfall presently.The result of the linear regression analysis of the data shows an increasing trend of rainfall with a decreasing trend in the temperature. Particle size analyses for fifteen (15) rock/soil samples taken from erosion sites at Okitipupa areas of Ondo State, indicate that the underlying rock/soil falls in the following clssifications; gravel (0.9%-1.7%) fine sand (11.3%-29.0%) and medium sand (69.3%-87.0%) respectively. This implies that the soil is predominantly sandy and can easily be vulnerable to erosion and if by chance of heavy rainfall in the area , the absorption of water by this soil will rapidly be exceeded to initiate erosion and by extension flooding. Governments at all levels should be prepared for such environmental contingencies as rainy seasons draw nearer .Government should also adopt a proactive and proper urban environmental management planning and mount a public sensitization on environment friendly impact of erosion and flooding on landforms.

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Table1: Monthly Mean Rainfall for Oshogbo, Ondo, Ibadan and Ikeja from Meteorological Agency, Oshodi.

Locations	**Jan**	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Oshogbo	6.04	24.31	70.83	119.07	157.43	186.06	160.83	125.49	213.33	198.08	33.78	5.55
Ondo	5.77	39.85	95.46	167.98	175.68	225.72	216.74	`160.61	243.28	159.77	38.16	9.60
Ibadan	5.10	29.33	75.98	134.25	152.97	180.61	176.97	138.96	184.55	170.40	22.60	9.98
Ikeja	14.07	41.52	67.91	136.54	186.42	281.20	182.41	88.93	193.64	139.05	65.85	21.94

Table 2: Monthly Mean Rainfall for Owerri, Enugu , and Umuahia from Agency Oshodi.

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Owerri	23.24	40.07	112.71	172.31	240.92	315.90	371.54	342.71	376.97	269.82	61.01	13.21
Enugu	5.76	16.21	55.49	140.70	232.53	256.78	259.75	244.74	295.17	213.81	17.54	7.62
Umuahia	15.68	46.66	126.99	244.29	232.20	314.13	284.73	281.82	279.14	208.86	36.78	11.98

Table 3: Computed Result of Rainfall Least Square Regression and Trend

Location	**Equation on chart**	**R-Squared Value on chart**	**Variation**	**Trend**
	Y	**R^2**	**%**	
Ikeja	2.4395x	0.0115	1.2	increase
Ibadan	3.003x	0.0222	2.1	increase
Ondo	2.849x	0.0141	1.4	increase
Oshogbo	4.618x	0.0454	4.5	increase

Similarly, the square regression values (r^2) for Owerri, Enugu and Umuahia show that the rainfall varies from 0.6 % to 5.2 %. with an increase in the trend of occurrence. (Table 4, Fig3)

Table 4: Computed result of rainfall least Square Regression and Trend

Location	**Equation on chart**	**R-Squared Value on chart**	**Variation**	**Trend**
	Y	**R^2**	**%**	
Enugu	6.827x	0.0445	4.5	increase
Umuahia	2.567x	0.0062	0.6	increase
Owerri	8.958x	0.0521	5.	increase

Table 5: Computed result of temperature least Square Regression and Trend

Location	**Equation on chart**	**R-Squared Value on chart**	**Variation**	**Trend**
	Y	**R^2**	**%**	
Ikeja	-0.218x	0.2022	20.22	decrease
Ibadan	-0.355x	0.3281	32.8	decrease

Ondo	-0.250x	0.2157	21.6	decrease
Oshogbo	-0.019x	0.1221	12.2	decrease
Enugu	-0.283x	0.313	31.3	decrease
Owerri	-0.233x	0.225	22.5	decrease

Table 6: Results of the particle size of the erosion sites

gravel =	1.7%
Coarse Sand =	10.2%
Medium Sand =	40.9%
Fine Sand =	35.9%
Fines =	11.3%

Gravel =	1.1%	Gravel =	1.1%
Coarse Sand =	11.2%		
Medium Sand =	39.0%	Sand =	71.1%
Fine Sand =	20.8%		
Fines =	27.8%	Fines =	27.8%

Gravel =	1.5%	Gravel =	1.5%
Coarse Sand =	11.0%		
Medium Sand =	36.4%	Sand =	68.7%
Fine Sand =	21.3%		
Fines =	29.9%	Fines =	29.9%

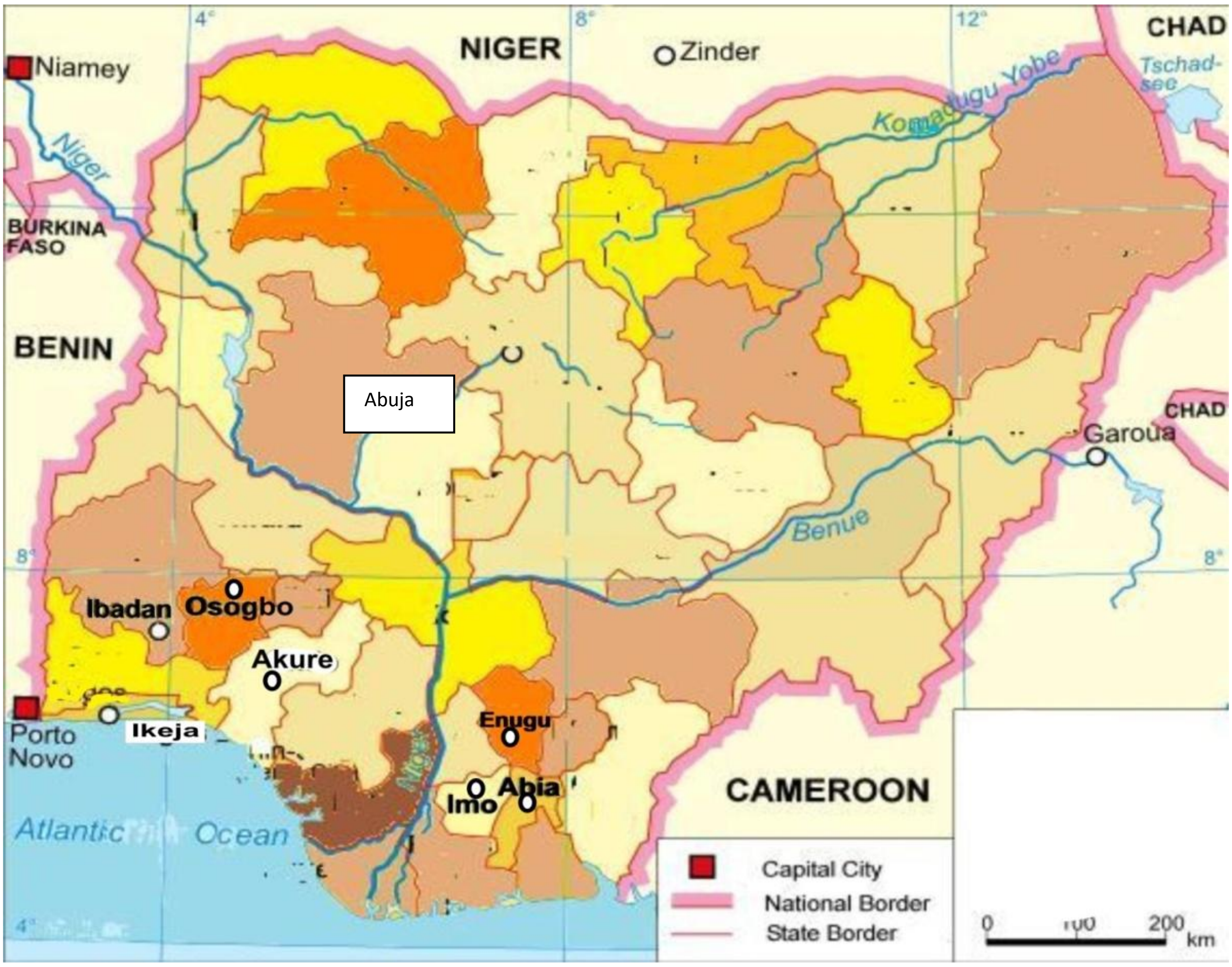

Fig 1 Map of Nigeria showing the study areas in the Southern divide of Nigeria

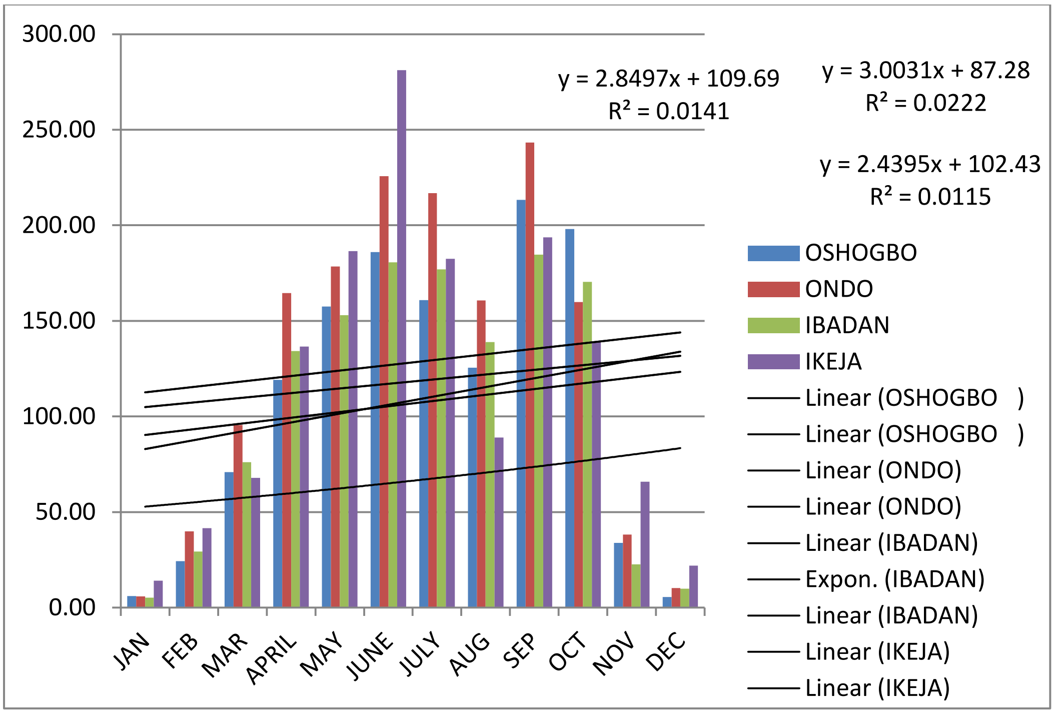

Fig 2: A histogram showing the linear trend of rainfall in Ikeja, Ibadan, Ondo and Oshogbo area

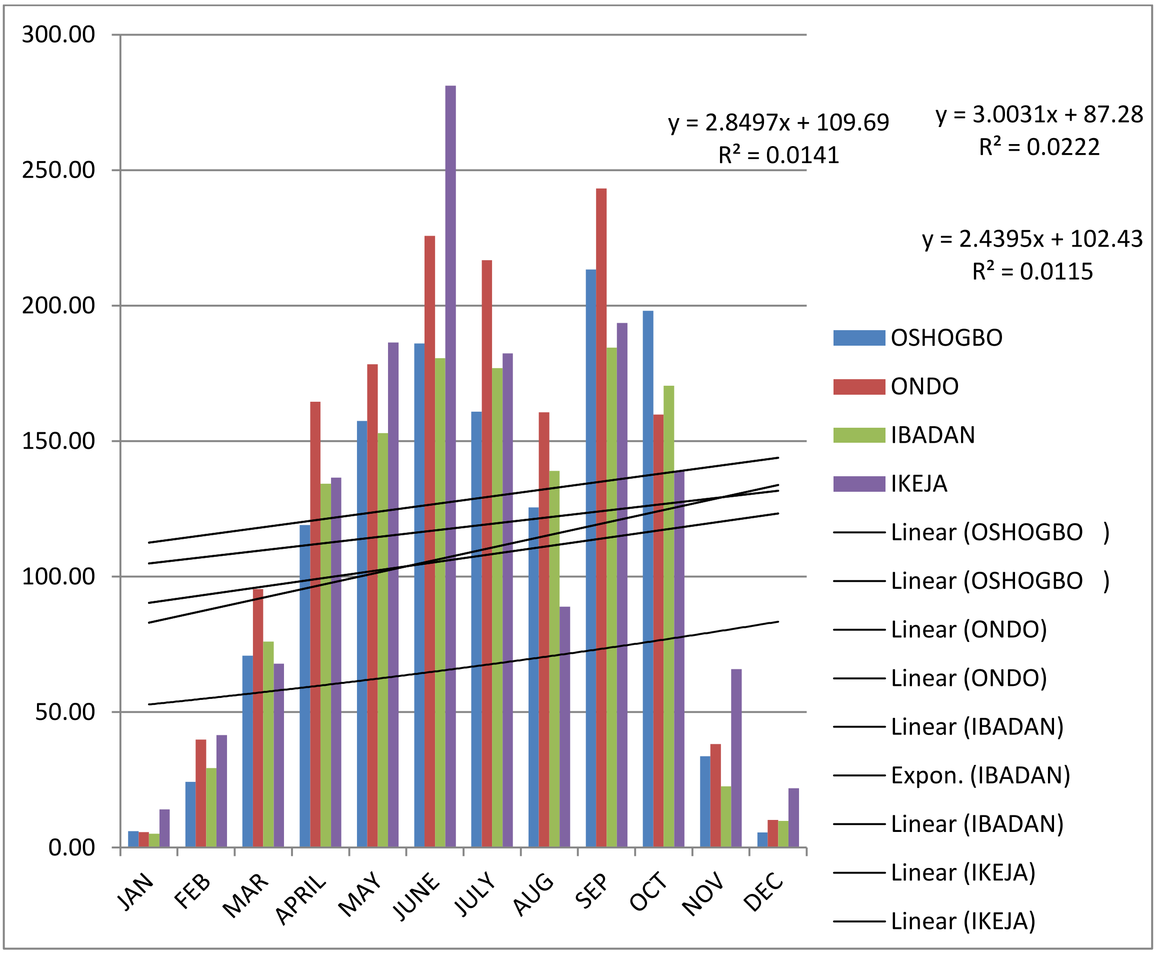

Fig 3: A histogram showing the linear trend of rainfall in Owerri, and Enugu area

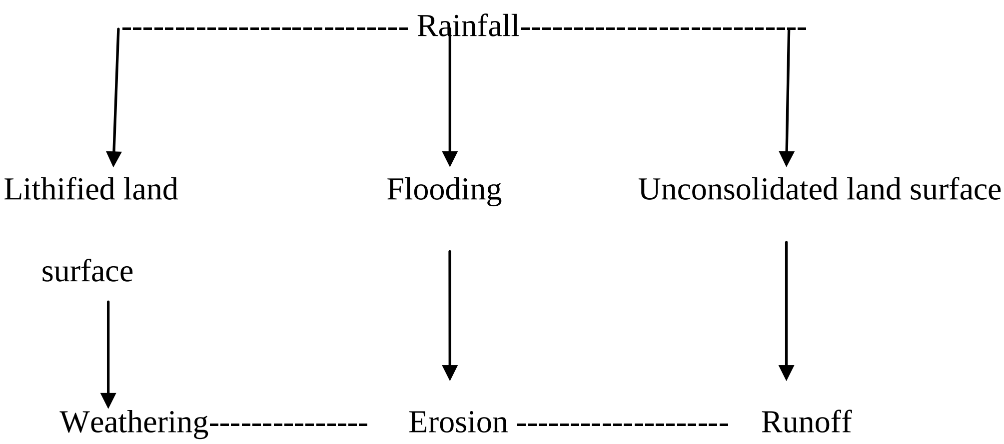

Fig 4: Pivotal roles of rainfall

Plate 1: Erosion and Flooding sites at Okitipupa area of Ondo