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Vulnerability of Soil Erosion in Okitipupa Area of Ondo State, Southwest Nigeria: A Climatic Problem.

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Abstract

Soil erosion is a natural phenomenon caused by a multidimensional factors. The soil vulnerability to erosion in Okitipupa area is studied with focus on climate and geotechnical characteristics as causatives. Rainfall and to a lesser extent temperature facilitate weathering, runoffs, flooding and erosion of any soil. Rainfall and temperature data of Ondo State were used for Okitipupa area since the latter is under the same climatic coverage. These data were grouped into decades for purposes of trend analyses. The results suggest that in the last three and half decades (1971-1980, 1981- 1990, 1991-2000, and 2001- 2007) the rainfall has been on the increase, an indication to show a change in the climate. The unusual increase in the trend of rainfall over time is attributable to the cause of flooding and erosion in Okitipupa area. Fifteen (15) soil samples subjected to atterberg tests ,particle size analysis, and permeability show the liquid limits of 18.3 to 44.3%, moisture content of 5.5-16.6% , fine- medium grained sand of 68.7% -96.2 and a low permeability respectively. These characteristics coupled with the increase in the trend of rainfall are suggested attributes that can make the soil vulnerable to runoffs, flooding and erosion. Dry season farming is suggested for those areas with high percentage of fine- medium grained sand. Government should discourage the construction of civil infrastructures along the coastal terrain of Okitipupa area.

Keywords *: Atterberg test, dry farming , particle size, permeability, vulnerability.*

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1 INTRODUCTION.

Soil is regarded as an engineering material or as a natural medium on which plants can grow to an agriculturist. To a civil engineer it is a material on which structures and highways are built but to a geologist it means the material that covers the bedrock and which needs to be removed or penetrated in order to reach the underlying rock or mineral deposits. The stability of the soil is therefore important. Water plays a vital role in the landscaping, formation, transportation and erosion of this soil. The amount of raindrops determines the quantity of water that infiltrates into the soil for the various roles. Similarly, the soil geotechnical characteristics determine the amount of water that will be allowed to infiltrate into the soil to cause flooding and erosion.Many scholars have suggested causes of gully erosion as surface runoff that is associated with rainfall events [1], natural and anthropogenic factors [2] natural and man's ignorance and unintentional action [3] and deforestation [4]. [5] suggested urbanization while[6] indicated severity and duration of storm that exceeds infiltration rate of the soil. Majority of authors agree that gully erosion primarily occurs as a result of rain drop impact that create rill that later develop into gullies. [7] is of the opinion that erosion is caused by traditional agricultural practice. This paper therefore aims at studying the soils particle size characteristics and its permeability in order to ascertain their contributory roles to erosion using the erosive power of rainfall and temperature as precursors.

1.1 Study Area

Okitipupa area lies between longitudes 4 ® 3' and 6® 00'East and latitudes 5® 42' and 8®15' North. The relative humidity is relatively high (75%) and annual rainfall of about 2000mm. The monthly mean temperature is 27®C while the range is 2®C. The area experiences wet and dry seasons that occur between march-November and November to March respectively. Major rivers like Oluwa, Akeun, Omiji and Chen flow through sedmentary rocks into the coastal lagoons. Okitipupa occupies a topography that is flat and undulating.

1.2 Geology of the area

Generally, there are two distinct geological regions in Ondo State, the region of the sedimentary rocks in the south to which Okitipupa belongs and the region of Precambrian basement rocks in the north. The sedimentary rocks are mainly of the cretaceous sediments and the cretaceous Abeokuta Formation . The Okitipupa area rises from the coastal part of Ilaje/Ese Odo to less than 15m above sea level. The area is characterized by sand ridges, lagoon and swampy flats of sedimentary terrain.

II. Materials and Methods

Fifteen (15) soil samples were collected from erosion sites around Okitipupa areas of Ondo State and subjected to particle size analysis and Atterberg tests. Rainfall and temperature data of Ondo State were also collected from the archives of the Meteorological Agency of Nigeria, Oshodi ,Lagos and used for Okitipupa since the areas are under the same climatic coverage. The data were modelled into three and half ($3^{1/2}$) decade partitions namely; 1971-1980, 1981-1990, 1991-2000 and 2001-2007 respectively and subjected to trend analysis statistical method. This method is used to ascertain if the variability positive or negative of rainfall and temperature have an influence on the susceptibility of the soil to erosion and flooding.

III. DISCUSSION

It is believed that flat terrains are susceptible to a wide spread of flooding known locally as water logging. [8] defined flooding as a temporary covering of land as a result of surface waters escaping from their normal confines or a result of heavy precipitation. He outlined three main types of flood as storm surge, river flood, and flash flood and special cases like water logging and backwater. Okitipupa occupies a flat terrain and most likely to experience flash floods and prone to widespread flooding in form of water logging. Flash floods are local events which are produced by intensive rainfall over a small area. Okitipupa has a land area of about 63 square kilometre with a population of 233,565 by the 2006 census. Table 1 shows the annual mean rainfall for the 1st decade (1971-1980) which increases from 1971 (281.40mm) reaching a peak in 1975 (464.00mm) and fluctuating from (243.60mm) in 1976 to (404.90mm) in 1980 giving an indication of rainfall changes over the years. An analysis of the monthly mean rainfall in Fig 1 indicates that the rains were generally high in July , and sharply dropping in August in what is known locally as 'August break' . The rainfall distribution in September is not uniform an indication of a shift in the rainfall pattern around the area showing by extension a change in the climatic condition.

Table 1: Annual mean rainfall for the 1st decade (1971-1980).

				RAINFAL		ONDO					
	1971	**1972**	**1973**	1974	1975	1976	1977	1978	1979	1980	1981
JAN	3.30	31.60	0.00	0.00	0.00	13.50	18.80	0.00	9.00	0.00	0.00
FEB	62.50	63.90	31.80	44.40	61.00	79.40	33.10	62.70	12.50	50.50	5.10
MAR	93.00	106.50	55.90	111.50	96.60	106.10	56.10	126.10	96.10	127.00	98.50
APRIL	127.30	80.70	120.90	191.50	221.70	137.30	138.10	288.20	115.40	188.50	140.20
MAY	146.90	151.40	189.90	182.80	301.50	172.20	164.90	203.50	140.00	133.70	165.90
JUNE	133.00	203.40	178.30	229.10	104.90	184.10	275.10	233.00	169.00	278.20	253.20
JULY	281.40	134.50	271.80	265.40	464.00	72.40	210.20	425.70	297.30	186.00	209.90
AUG	80.10	105.90	276.10	153.30	110.10	89.70	106.20	72.10	290.70	404.90	150.30
SEP	0.00	205.90	177.50	330.10	130.70	89.40	104.90	296.40	364.20	348.60	183.00
OCT	109.50	120.00	154.40	133.00	206.20	243.60	188.40	168.40	173.90	303.80	132.60
NOV	60.50	2.30	2.80	16.30	82.10	81.00	3.40	8.40	100.70	52.00	49.70
DEC	25.20	38.60	16.00	0.00	36.10	0.00	39.80	1.80	4.70	21.90	0.00
ONDO	93.56	103.73	122.95	138.12	151.24	105.73	111.58	157.19	147.79	174.59	115.70

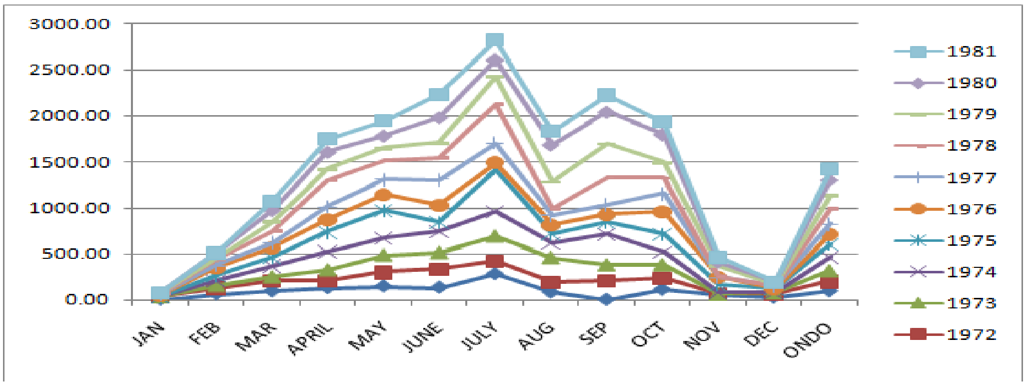

Fig:1 Annual mean rainfall distribution in 1971-1980 decade

In the second decade (1981-1890) Table 2, the annual mean rainfall was least in 1984 (24.48mm) and maximal in 1985 (174.24mm) .Many months were without rainfall in this decade .

Table 2: Annual mean rainfall (mm) for 2nd decade (1981-1990).

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	00.0	9.60	0.00	0.00	0.00	4.60	0.00	3.70	0.00	12.10
Feb	5.10	101.40	17.80	1.40	41.90	125.40	32.10	92.30	0.00	1.20
mar	98.50	60.50	34.70	171.20	212.80	190.70	145.40	93.90	115.00	0.00
April	140.20	208.50	0.00	121.20	513.30	41.60	91.20	193.80	200.70	140.90
May	165.90	165.40	158.50	0.00	410.70	211.10	86.60	240.40	245.10	121.00
June	253.20	158.90	282.60	0.00	259.80	271.90	140.80	223.40	230.00	197.20
July	209.90	156.10	129.40	0.00	335.40	170.60	244.40	141.70	300.30	210.40
Aug	150.30	44.70	45.30	0.00	285.00	102.20	355.10	101.40	210.50	115.50
Sept	183.00	185.60	312.10	0.00	0.00	256.90	230.70	301.70	158.90	277.30
Oct	132.60	186.40	80.20	0.00	0.00	132.30	263.20	244.80	124.20	150.00
Nov	49.70	14.50	46.90	0.00	32.00	23.40	0.80	27.70	23.60	76.00
Dec	0.00	0.00	22.00	0.00	0.00	0.00	6.60	29.70	0.00	55.80

Mean 115.70 107.63 94.13 24.48 174.24 127.56 133.08 141.21 134.03 113.12

Fig 2 gives a picture of the variations which conform with the usual rainfall pattern of the studied area or any other area within the climatic region. The rainfall scenario indicates a clear reversal of rainfall distribution pattern ever known as rain was highest in April (513.30mm) of 1985 and there was the usual 'August break' which showed decreased amount of rainfall. Generally ,the rainfall distribution in this decade conform with the usual trend of wet and dry seasons known in the region except the unusual heavy downpour in April . The unusual heavy rainfall in April is significant for it suggests a shift in the seasonal rainfall pattern and this agrees with the opinion of [9] that in many places the hydrologic impact of climate change on floods may not primarily be due to the increased annual rain depth but to the shift in the seasonal rainfall pattern. The June and September peaks of rainfall in Fig 2

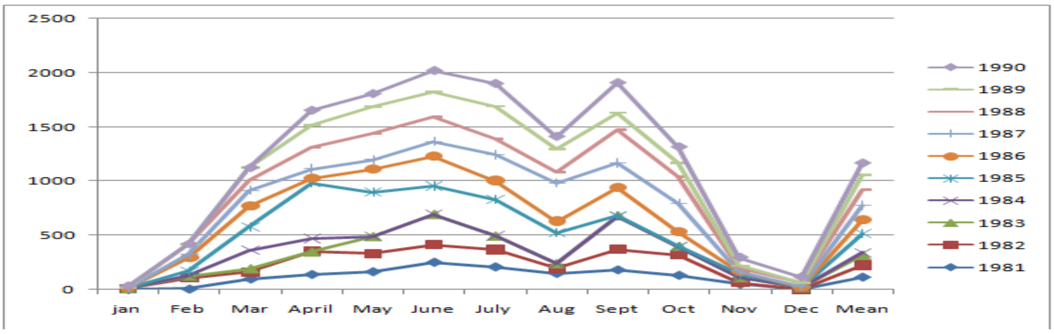

Fig 2: Annual mean rainfall distribution in 1981-1990 decade

may initiate a serious flood events in any place. The April downpour can cause a flash flood which may result in water logging in places but the follow up rainfalls may lead to erosion and flooding.

Table 3 shows that the total mean annual rainfall for the decade (1991-2000) ranges between 101,93mm in 1994 and 192.52mm in 1991 respectively.

Table 3 Rainfall distribution in the 3rd decade (1991-2000).

	1991`	1992	1993	1994	1995	1996	1997	1998	1999	2000
Jan	0.00	0.00	0.00	31.30	0.00	5.40	27.60	0.00	3.20	0.00
Feb	55.30	4.90	34.60	50.90	49.80	93.20	0.00	23.20	21.20	0.00
Mar	171.20	74.90	121.00	74.50	101.00	141.30	0.00	0.20	69.20	87.20
April	295.30	96.70	100.10	186.20	130.70	187.20	219.40	108.90	132.00	187.60
May	204.20	196.10	152.40	192.70	124.60	187.40	219.50	228.50	120.50	124.80
June	281.30	223.90	195.30	263.30	407.50	236.00	276.40	254.60	236.10	384.70
July	552.20	185.00	91.70	0.00	251.30	236.80	71.90	210.90	335.10	169.40
Aug	223.60	52.00	219.40	0.00	319.40	190.90	76.20	40.80	170.70	198.00
Sep	309.60	488.20	351.20	219.10	348.80	302.20	230.10	241.40	253.60	216.30
Oct	204.90	131.40	88.30	165.90	244.30	175.00	187.70	332.30	259.30	176.30
Nov	0.00	67.10	90.30	39.20	36.60	1.60	23.70	63.80	63.80	23.40
Dec	12.60	0.00	5.60	0.00	0.00	0.00	32.70	0.00	0.00	0.00
Mean	192.52	126.68	120.83	101.93	167.83	101.93	120.68	113.77	125.38	138.73

Fig 3 shows a general rainfall distribution for the decade with two distinct rainfall maxima in June and September and a noticeable variance (552.20mm) occurring in July of 1991.The spatial distribution of rainfall in this area indicates regularity in time and space. When rain falls regularly there is the tendency for the soil/ground to get fully saturated and under this condition the soil/ground capacity to store water may be exceeded thus forming runoffs that may escape to cover the surface of land as flood.

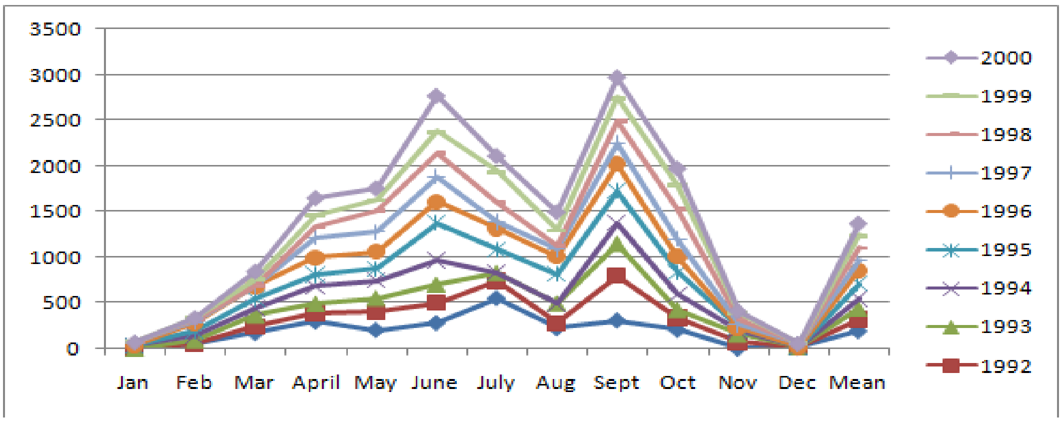

Fig3: Annual mean rainfall distribution in 1992-2000 decade

Table 4 gives the total annual mean rainfall for 2001-2007. The distribution of rainfall indicates that the values vary from 112.96mm in 2001 to 140.90mm in 2003. The dry and wet seasons are clearly shown in Fig 4. The distribution of rainfall is consistent with the pattern in the region showing a single rainfall maximum in September. Rainfall consistency and intensity give rise to runoffs which cumulates to flooding. A general trend analysis of the rainfall for the decades is shown in Fig 5.

Table 4 Rainfall distribution in 2001-2007.

	2001	**2002**	**2003**	**2004**	**2005**	2006	**2007**
Jan	11.1	0	16.3	4.8	0	7.7	0
Feb	0	11.7	12.7	78.2	12.1	49.1	57
Mar	84.7	124.3	53.8	49.2	161.4	101.1	19.3
April	253.3	175.4	297.5	173.1	108.6	62	113
May	219.4	98.8	111.1	171.6	248.2	189.9	220
Jun	199	264.9	193.2	207.9	298.3	269.3	154
Jul	333.2	294.4	61	171.9	314.6	155.4	77.5
Aug	91.1	237.6	81.4	170.4	30.1	358.9	383.1
Sept	274.8	148.4	556.6	354.1	278.2	183.8	291.1
Oct	66.4	0	184	197.5	142.4	103.9	137
Nov	56.6	0	123.2	37.4	38.4	23	19.9
Dec	1.1	0	0	0	17	4.5	5.4
Mean	132.56	112.96	140.9	134.68	137.44	125.72	123.11

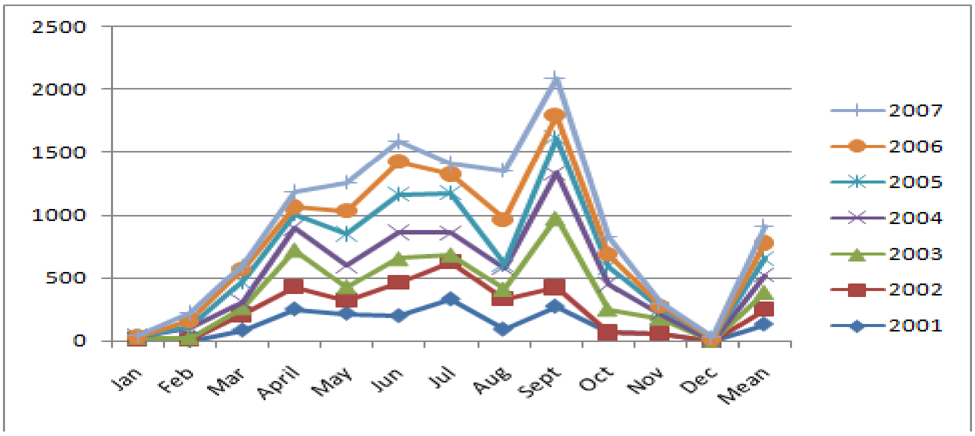

Fig 4: Annual mean rainfall distribution in 2001-2007 decade

The trend analysis suggests that in the last few decades (1971-2007) the rainfall has been on the increase, an indication that climate is positively changing over the years. The increase ranges from y=1.684 to y=3.716 (Fig 4). [10] states that in the Nigerian context an unusual increase in the rainfall and temperature over time can cause massive erosion and flooding which are attributable to climate change. However, while the rainfall increases in the studied area the temperature slightly decreases from -0.25 to -0.1 (Fig 6).

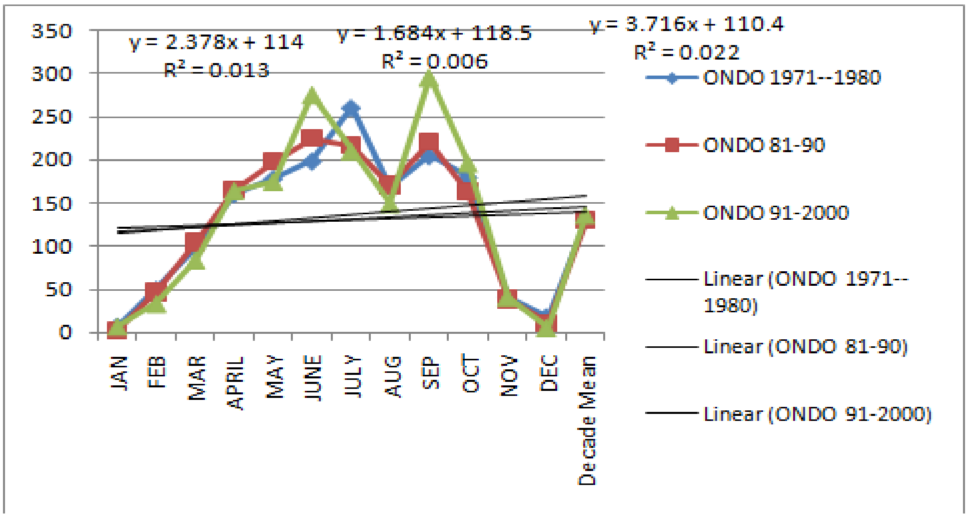

Fig 5: Trend analysis of the decades 1971-2007

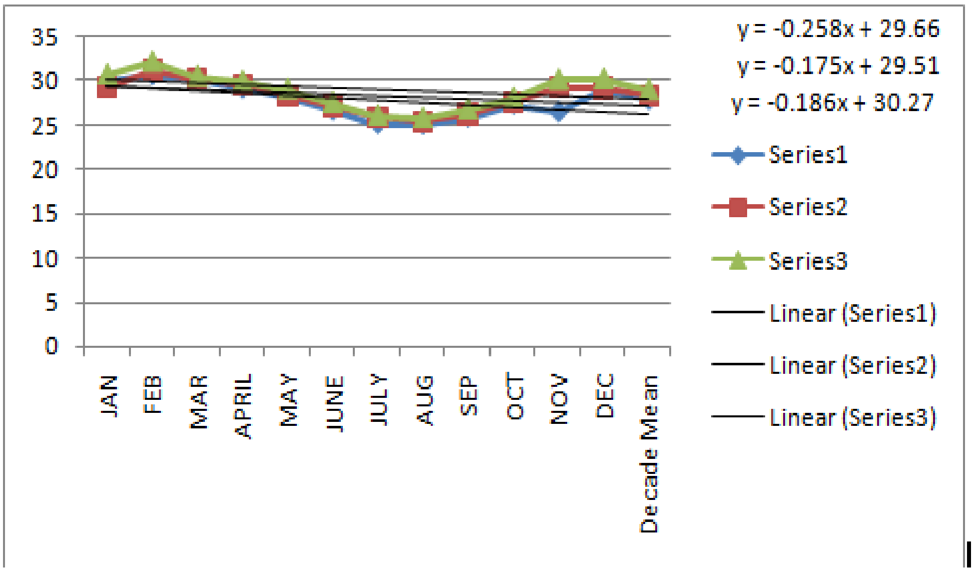

Fig 6: Temperature trend for decades 1971-2000.

3.1 Soil test

Fifteen (15) soil samples were collected from the erosion sites (Fig 7) and subjected to atterberg test, particle size analysis and permeability tests.

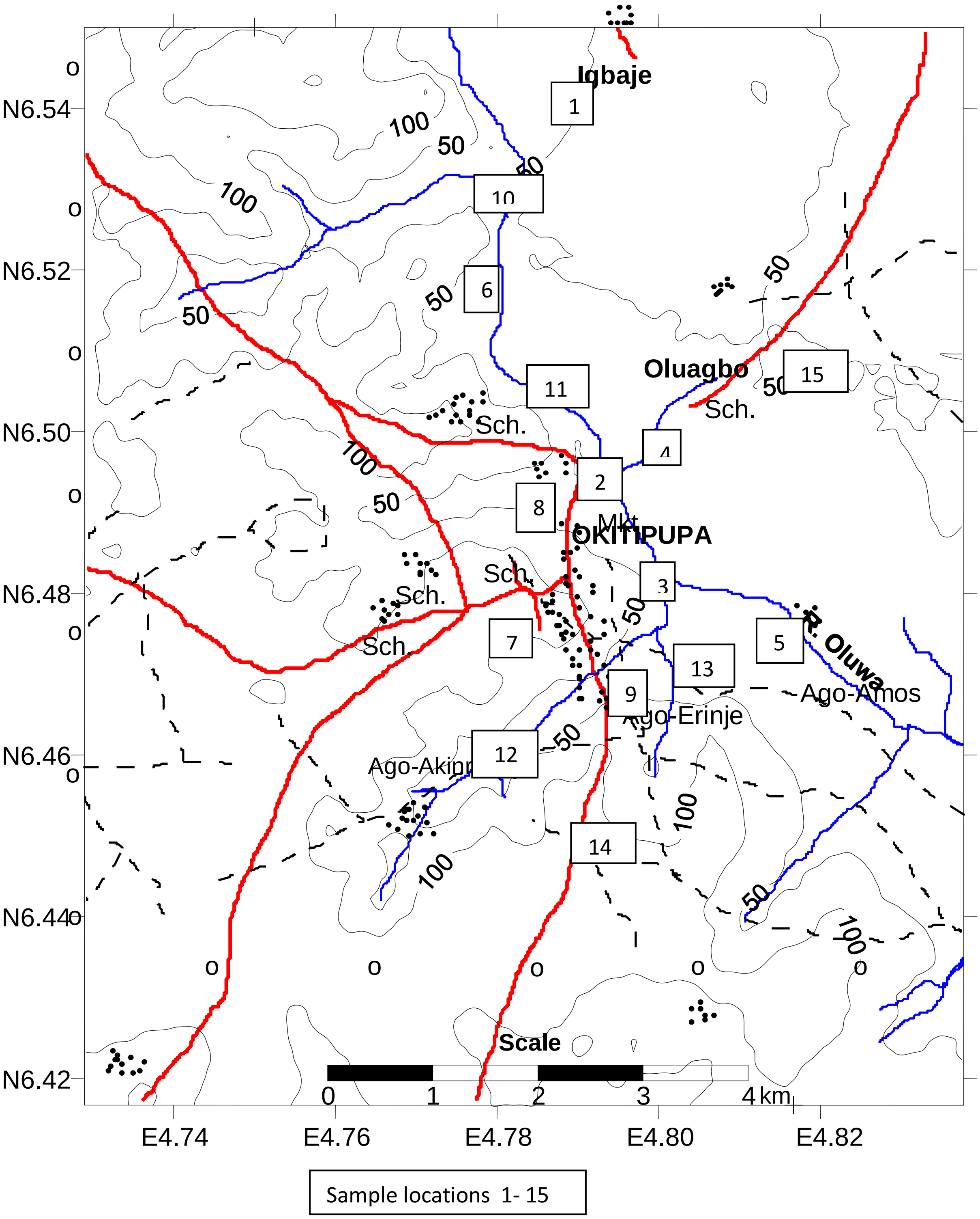

Fig 7: Sample locations in Okitipupa areas.

Table 5: Atterberg Test

S/N	Liguid limit %	Moisture Content	Plastic Index	Consistency Index	Plastic Limit %	Flow Index	Swell Index	Liquidity Index
1	18.3	5.5	0.00	>1		6.59	0.30	Negative
2	36.7	10.6	14.50	>1	22.2	6.59	0.29	-ve
3	37.6	12.2	16.15	>1	21.5	6.59	0.32	-ve
4	33.1	12.0	11.40	>1	21.70	6.59	0.36	-ve
5	34.6	8.8	12.90	>1	21.70	6.59	0.25	-ve
6	42.2	15.7	18.75	>1	23.5	6.59	0..37	-ve
7	37.8	13.4	14.50	>1	23.3	6.59	0.37	-ve
8	44.3	16.6	21.90	>1	22.4	6.59	0.37	>ve
9	22.0	6.2	0.00	>1	none	2.19	0.28	>ve
10	36.7	14.5	14.30	>1	22.4	6.59	0.39	>ve

Table 5 shows that the values of the liquid limit (LL) of the soils range from 18.33 to 44.3%, the moisture content from 5.5 -16.6% and plastic limit (Pl) from 21.5 to 23.3% respectively. These values were recorded in May 2012 at the start of rainfall in the study area. The tests on the degree of coefficient of permeability (falling head) indicate low for most of the soil samples and medium for one sample only. Table 6 shows the result of particle size analysis of the soil from erosion site at Okitipupa (Plate 1)

Plate 1: An erosion Site

The result shows that the percentage of sand ranges from 68.7% to 96.2% while gravel varies between 0.9 to 2.0 %. The fine particle contents varies from 2.8 to 29.9%.

Table 7 Particle Size Analysis (%)

Sample	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Gravel	0.9	0.9	2.0	1.5	1.3	0.9	1.1	0.0	1.7	1.1
Sand	96.2	71.3	69.0	68.7	70.2	74.6	69.3	70.3	87.0	71.1
Fine	2.8	27.8	29.0	29.9	28.5	24.4	29.6	29.7	11.3	27.8

The fine particle contents in the soil establish the presence of silts and clay sediments. Sediments with high sand (Fine-medium) or silt contents with less clay particle erode easily under a flat terrain. Based on these soil textures, the soil/ground of Okitipupa area is dominantly sandy and is therefore vulnerable to erosion and by extension flooding. Since the result of the coefficient of permeability of the soil has been established to be low, it implies that less water will move underground and more runoff will be generated to cause erosion. With increased rainfall flooding on a flat plain will be readily promoted. The porosity and permeability of any soil affect the speed at which water can percolate or infiltrate into the ground .

3.2 Control measures.

Okitipupa is one of the active farming areas in Ondo State, Nigeria. The activities of farmers can promote erosion through an unscientific farming method. Dry season agricultural practice is advocated since the area is coastal and surrounded by lagoon, and creeks .in order to reduce erosion issues. Since the terrain is topographically flat with fine-medium sand and silt coupled with low permeability, vulnerability to erosion is certain, efforts should be made to avoid the removal of vegetative cover. Civil and infrastructural construction work should be avoided along the coast and erosion vulnerable areas.

IV. CONCLUSION

Okitipupa lies on a topographically flat terrain with fine-medium grained sand and silt/clay contents. These characteristics along with low permeability make the soil vulnerable to erosion. Dry season farming is advocated. Government should mount gingles in the radio and television to educate the public on how to avoid creating avenues for erosion along the coastal areas.

V. Acknowledgement

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