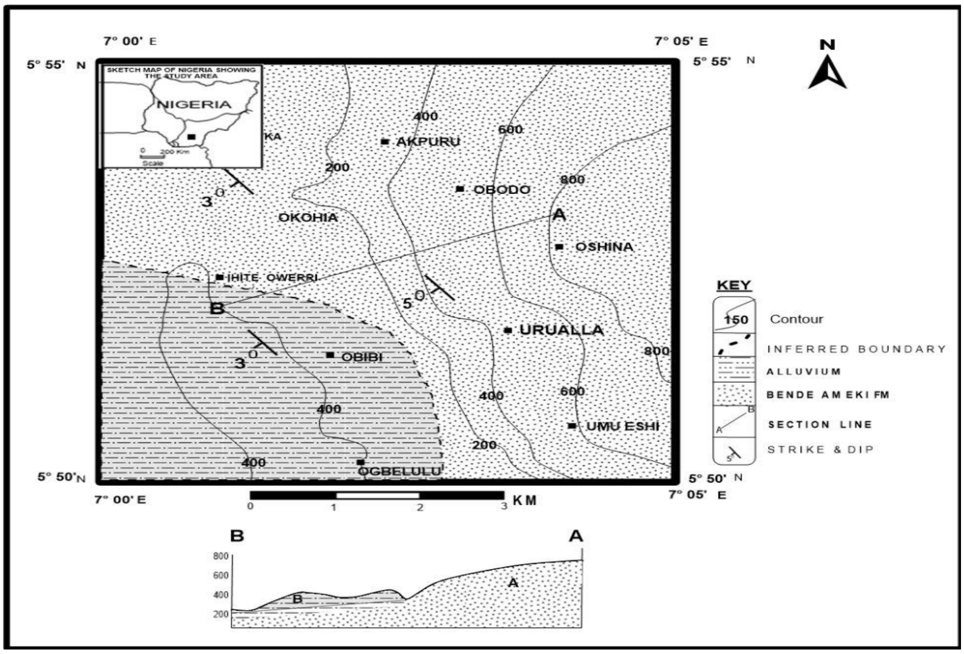

Figure 2: Geologic map of the study area

3. Materials and Methods

Desk, field and laboratory studies were used. Desk studies involved gathering all available published and unpublished works on the area in order to obtain sufficient background information on Urualla. Field work involved identification of major gully erosion sites and discussions with affected community residents and collection of soil samples from the erosion sites. Soil samples were collected from the gully erosion sites using the protocol established by Spangler and Handy (1973). After the sampling, a number of geotechnical tests ranging from particle size analyses, Atterberg limits (eg plastic limits and shrinkage limits), compaction and shear strength tests were conducted on the samples using the procedures developed by American Society for Testing Materials (ASTM) and the British Standard Methods for testing soils or Civil Engineering applications (B.S., 1377 - 1990).

4. Results and Discussion

Table 1 shows the geotechnical properties of the soil samples taken from gully erosion sites at Urualla.The values of liquid limits for the area ranges from 29.1% to 36.0% which correspond to silt values. The plastic limits vary from 14. 0% to 18.1% while the plasticity index varies from 14.3% to 18.2%. The Atterberg Limits of soils include the liquid limit, shrinkage limit and plastic limit.

These limits basically try to determine the water contents of fine grained soils and also help to distinguish between silt and clay. When the water contents of these soils exceed these values, the soil will flow like a liquid. It is obvious that the saturated hydraulic conductivity of these soils will increase during intensive rainfall events. This will increase the water content of the soil and make it more erodible. Hence there is a connection between rainfall erosivity, saturated hydraulic conductivity and these Atterberg limits.

Table 1 also includes the results of particle size analysis in the form of coarse sand, medium sand and fine sand percentages. The dominant size is fine sand which has between 50% - 56% of the particle sizes population.

Table 1: Geotechnical parameters of soils at gully erosion sites in Urualla

Parameter		*Oshina*	*Obodo*	*IhiteOwerri*	*Obidi*	*Ogbelul*	*Akpuru*
Liquid Limits L. L. %		32.4	29.1	36.7	35.1	36	31.1
Plastic Limits P. L. %		18.1	14	18.5	18	18.1	16.3
Plasticity Index P.I %		14.3	15.1	18.2	17.1	17.9	14.8
Particle Size	Coarse Sand %	12	10	13	14	12	11
	Medium Sand %	24	27	23	24	22	26
	Fine Sand %	53	51	54	56	55	55
Dry Density g/m^3		1.89	1.85	1.92	1.89	1.81	1.89
Max. Dry Density g/m^3		1.91	1.91	1.93	1.92	1.91	1.91
OMC% Optimum Water Content		12.5	12.9	13.1	13.5	13.3	12.7
Water Content %		7.4	9.7	11.9	11.5	13.7	13.6
Cohesion (KN/m^2		20	20	15	13	10	1.9

According to Hjulstrom, fine sand is the easiest to be removed by runoff. It isestimated that 20.2% of the precipitation from the Urualla catchment area drainss off as runoff. The high energy of runoff in the area would remove most of the silt/fine size populations of the Urualla soil hence increasing its erodibility. Although the plasticity indices (P.I) for these soils is greater than 5, FAO (2013) has shown that fine sands are highly susceptible to internal erosion (piping) because they have large pores and also lack the necessary cohesion to keep the particles together. The values of dry density range from 1.81g/m^3 to 1.92g/m^3 while maximum dry density values go from 1.91g/m^3 to 1.93g/m^3. The optimum moisture content goes from 12.5% to 13.5% and is consistent with soils containing a mixture of sand – silt – clay particles which easily yields to erosion. The cohesion values range from 10KN/m^2 to 20KN/m^2 which again corresponds to silty – loam soils. From these geotechnical parameters of Urualla soils, it is clear that they have low shear strength.

A modified form of the USLE equation was used to compute the average soil loss in Urualla per year. This is given by equation 3:

$E = R*K*L*S*C*P$ (3)

where A = Estimated average soil loss per acre per year.
R = Average rainfall for the previous 20 years
K = Soil erodibility factor
L = Slope length factor
S = Slope steepness factor, usually this is the same as the dip amount
C = Management factor (Organic manure)
P = Support practice factor

Evaluation of equation 3 led to 2002 tons per acre per year as the average soil loss in Urualla and a K (i.e. soil erodibility) value of 0.4. This shows that the volume of soil lost every year to erosion in Urualla is very high. It has been established that soil erodibility can be influenced by rainfall factors like size of rain drops, rainfall intensity, duration and even speed of run off (Gobin et al, 1999; Obi and Salako, 1995).
From the works of Lal and Elliot (1994) and Gonzalez-Hidalgo et al.,(2007), it is clear that the soil erodibility and the erosivity of rainfall play significant role in the creation and sustenance of gullying processes. This view is supported by Baffour et al. (2012). While erodibility is a function of the soil structure and use, erosivity deals with the aggressiveness of rain and its ability to initiate erosion. In measuring erosivity,

the physical dimensions of rain drops become relevant. Obi and Salako (1995) measured physical dimensions of rain drops in Nsukka, another town in southeastern Nigeria that is also prone to gully erosion and found that medium raindrop sizes ranged from 1.1 to 2.9mm during the very erosive months (between May and August). In other words, the aggressiveness of rainfall events also promote erosional processes. A modified version of the Fournier index used in Baffour et al. (2012) was used to estimate rainfall erosivity for Urualla. Rainfall at the study area peaks between May and September (Ofomata, 1985). Values obtained by the evaluation of equation 4 for Urualla range from 75mmh^{-1} to 126 mmh^{-1} which far exceeds the 25mmh^{-1} threshold value suggested by Hudson (1981). In other words, Urualla by virtue of its rainfall erosivity has great risks of erosion. The rainfall erosivity for Urualla was estimated by using equation 4.

$Cp = P^2max/P$ Where Cp = Fournier index (mm)
Pmax = rainfall amount in the wettest month (4)
P = annual precipitation (mm)

If the values of the geotechnical results are integrated with the soil erodibility factor, K = 0.4 and erosion risk due to rainfall erosivity as summarized in table 2, it is then clear that gullying processes in Urualla are inevitable. Again, the table shows that K >0.4 which is common in silty soils. Plate1 shows the various erosion sites in Urualla.

Table 2: Relationship between erodibility, soil type and grain size

K –factor value	Erodibility	Soil Type	Grain Size(mm)
→ 0. 4	High	Silt	0.016 – 0.062
0.25 – 0.4	Moderate	Silt - loam	0.004 – 0.016
0.05 - 0.2	Low	Sandy soil	0.062 – 1.19
0.05 – 0.15	v. low	Clay	0.001 – 0.004

Plate 1: Various erosion sites in Urualla, Imo State

5. Conclusion

Urualla and environs are underlain by rocks and soils belonging to the Eocene Ameki Formation. The soil cover over the geologic formation range from Arenosols and rhodicferralsols. Arenosol soils host the major gully erosion sites in Urualla. Geotechnical properties of the soils, soil erodibility and rainfall erosivity values determined for Urualla have shown that the soils are highly susceptible to erosion. It is therefore suggested that future studies of soil susceptibility to erosion should always integrate geotechnics with concepts of erodibility and erosivity in order to achieve a deeper understanding of the problems of gully erosion. This integrated approach will provide a better framework or preventing the formation of deep ravines and gullies that are ravaging southeastern Nigeria and perhaps save more lives and properties.

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