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Soil Characteristics in a Gully Erosion Site, Asase, North Bank, Makurdi, Nigeria

Malum Japhet Flayin[1]*, Burbwa Annord Kuma[2], Sini Vaisa Jonathan[3]
[123]Department of Agricultural and Environmental Engineering, Joseph Sarwuan Tarka University, Makurdi, Nigeria

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ABSTRACT

An assessment studies of some soil properties in gully erosion site at Asase town into River Benue embankment(4km), in Makurdi Benue State was carried out. Morphometry study of the erosion sites' length, width, depth and nature of the erosion was done. Soil samples from five sites (A-E), at the top, middle and bottom of the gully were collected, giving a total of 15 soil samples and analyzed. Results showed all site soils were mostly dominated by loosed and very porous sandy constituents with low proportion of silt and clay. The textural class of the soils were sandy-loam. The entire site mean for moisture content was 11.26% (low), bulk density, 1.40 g/cm3(low) while porosity value was 47.70%. The mean physico-chemical properties of organic carbon showed low value of 0.34%, organic matter 0.60% (low), nitrogen content 0.33% high, phosphorus value 0.36mk/kg, low, potassium 0.25 cmol/kg (medium), sodium 0.22 cmol/kg (medium), magnesium 2.32 cmol/kg (high), calcium 2.57 cmol/kg (medium), hydrogen potential(pH) value of 6.14, showing that, the soil is slightly acidic while the exchangeable cation capacity (CEC) was 6.41 cmol/kg (medium). The entire result showed bulk density and soil particles are not consolidated, resulting in poor binding nature of the soil, therefore when impacted on by flood water, it erods. This explains why the gully walls easily collapse, creating deep and wide gullies in the sites. It is recommended that mitigation of gullies of these nature, is to construct concrete trapezoidal drainage channels after proper analysis of the soils in the area.

***KEYWORDS**: Assessment, Soil properties, Gully erosion, Physico-chemical, Makurdi*

1. INTRODUCTION

Soil is often regarded as the most vital earth's natural resources. It hosts both animate and inanimate things. Over three quarters of the world's manmade development are on it. Soil erosion is the removal of weathered loose soil materials from the ground surface by naturally occurring agents through the detachment and transport of soil materials from one location to another, usually at a lower elevation ((Jim, 2015; HCCC, 2015; EB, 2017).

Water is the predominant agent of erosion on sites (Dehne, 2015; Arthur and Dean, 2017). Wind erosion is not considered a major contributing factor to erosion except in deserts and desertificated savannah areas because of the localized nature of the exposed soil areas. However, many of the methods effective in reducing erosion caused by water are also effective in reducing erosion caused by wind, (CEF, 2017).

Some natural agents are also mostly responsible for this phenomenon but the extent to which erosion occurs can be considerably accelerated through human activities. A United Nation (UN) convention to combat land degradation (CCD) opines that soil erosion automatically results in reduction of loss of the biological and economic productivity and complexity of terrestrial ecosystems,(Claasssen, 2004). Gully erosion is regarded as the single most important environmental degradation problem in the developing world, (Ananda and Herath, 2003). The Nigerian environment is degraded through the menace of soil erosion in several parts of the country. Hundreds of people are directly affected every year and have to be re-located because large areas of lands are becoming unsuitable for human settlements (Mbaya, 2012; Lombard, 2016).

Evidence that gully erosion is one of the major devastating catastrophe that speed up soil erosion was studied (Shit and Maiti, 2012). The incidence of this hazard signifies a severe type of land degradation that deserves a very exceptional consideration. The impact of gully erosion has attracted the attention of many scholars who came up with emerging views that gully erosion caused a significant soil losses and water, decrease crop yield, degradation of ecosystem, road and bridges, farmlands as well as settlements was identified(Conoscenti *et al*, 2014; Torri *et al* 2014, and Boardman ,2014). This study has discovered a serious hole regarding the menace of gully erosion in the study areas and the potential threat posed to human lives, roads, bridges and farm lands(NGI, 2017).

Investigation on gully erosion in Urban Areas and showed that gully erosion occurs due to extreme overflow of fluid with a very high speed and energy to remove and transmit soil particle downhill slope,(Ehiorobo and Audu, 2012). In Nigeria, several of the gullies that occurred in towns were due to inappropriate termination of drains and stream paths, the increase in gullies pool by the side of a few water courses resulting from changes in land use practice remained a source of worry. Many scholars have examined the vulnerability of soil to inter rill and rill erosion,(Jenkins 2015; Ghimire, 2016), but little research explored the propensity of soils to gully erosion. Gully formations can be difficult to control if remedial measures are not designed and properly constructed.

Cases of gully erosion have been causing devastating damages to farm lands and homes especially in this era of climate change. Most of the causes are due to negligence, improper town planning, building on water ways and blocking of drainage channels. In areas where drainage channels are constructed, the soils properties are not properly studied therefore they collapse or are over flooded by runoff. Asase Village, North Bank area in Makurdi town falls within this category of erosion problems with formation of gullies that has already become a serious environmental disaster for the people living in the area (Plate1). Therefore, solving the gully erosion problem in Asase village North Bank Area 2 in Makurdi town requires conjunctive research efforts.

The objectives of the study was to assessed erosion characteristics of the soil from Asase village(4km) into river Benue embankment in North Bank, Makurdi town.; and to proffer an engineering solution towards mitigating the erosion problem in the area.

2. MATERIALS AND METHODS

2.1 The Study Area

The study was conducted in Asase drainage basin, in North-Bank catchment area of Makurdi metropolis, Benue state. Makurdi is the capital of Benue state (Figure 1). The study area is located between longitude 8° 36^{1} 0^{11} and 8° 36^{1} 12^{11}, as well as between latitude 7° 47^{1} 02^{11} and 7° 47^{1} 15^{11}(MLSM, 2016). Makurdi has a population of about 292,645 inhabitants (Iorkua, 2006). The annual total rainfall ranges from 900mm to 1800mm, with an average annual intensity of 44.85mm/hr.

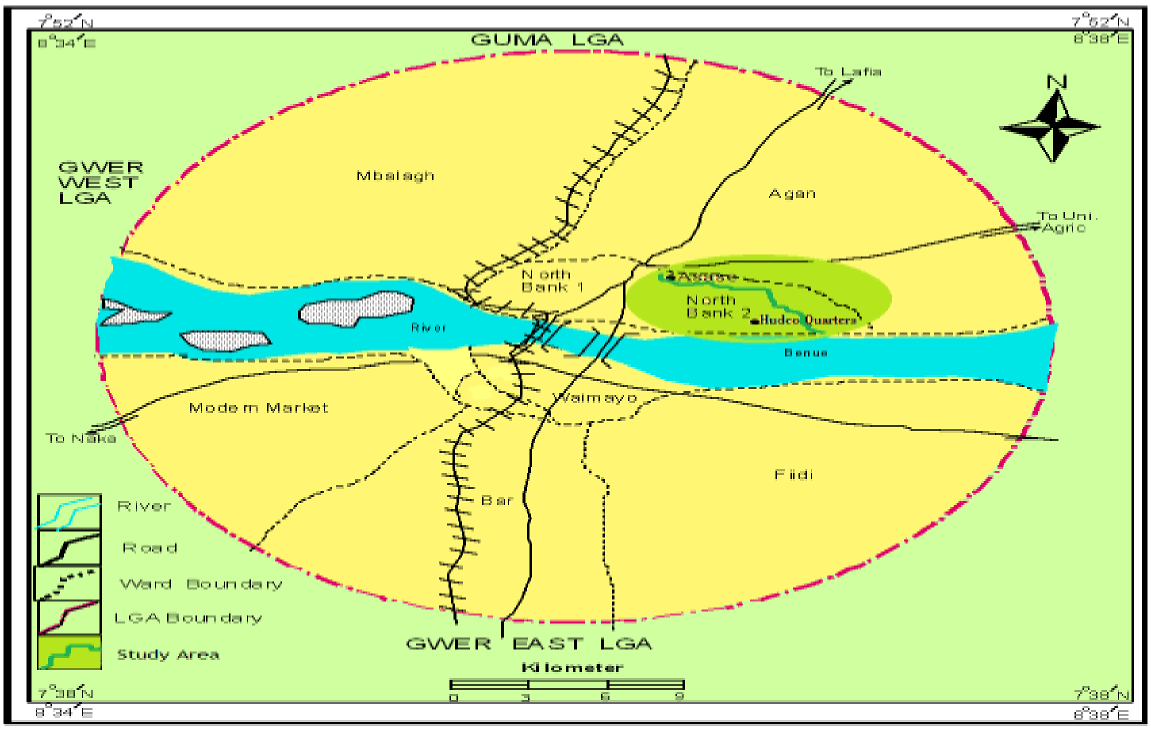

Figure 1: Map of Makurdi showing Study Area in North Bank 2

The mean annual maximum temperature range between 22°C to 37°C and relative humidity ranges from 50% to 80%(WMO, 2017). The occupations of inhabitants of Makurdi are farming, fishing, trading as well as Civil servants.

The geology of Makurdi composed of sedimentary rocks, dominated by sandstones. The sandstone is divided into micaceous and Felds phatic sandstones. Soils of the study area reflect the geology of two major soil types (Nyagba,1995); hydromorphic soil (developed on alluvium sediments found along the River Benue) and red ferrosols. Makurdi town is drained principally by river Benue which divides it into Makurdi North and South banks with an undulating terrain slope angle hardly exceeding 10,(Ologunorisa and Tersoo, 2006).

Reconnaissance survey of the areas affected by gully erosion was done. Field measurements of morphological parameters of the gully of length, width and depth was carried out and recorded manually. The distance from Asase village (beginning of gully erosion site) to the river Benue embankment was 4km (MLSM, 2017). The study area from the starting point (Asase) to the end point (river embankment) was divided into 5 distant points A, B, C, D and E respectively (Plate

1). The slope and depth of the gully which varied at various study points were measured and recorded using relevant standard field instruments.

2.2 Sample Collections and Analysis

Soil samples were collected from mapped site (A to E) along gully side walls of the gully using a 30 m linen tape stretched along gully wall layer profiles to the toe of the gully. Augur and hand-held shovel were used to collect the samples at 0 to 0.5m, 0.5-1m, 1-2m, 2-3m, 3-4m depths from each of the 5 sites and kept in polythene bags, labelled and named after the gully erosion site and taken to laboratory for analysis.

3. RESULTS AND DISCUSSION

3.1 Results

The erosion characteristics of the study area with respect of to their gully length, width, depth and nature of the erosion are shown in Table 1. The grain size analysis of the soil particles from the study sites (A-E) with respect to the textural class, percentage composition of sand, clay and silt are tabulated as shown in Table 2. Table 3 showed the detail results of the soil physical properties analyzed in the laboratory pertinent to moisture content, bulk density, permeability and porosity. Analysis of the chemical properties of the soils from the entire study area are recorded and shown in Table 4.

3.2 Discussion

3.2.1 Erosion characteristics of the study area

The erosion characteristics of the study area gives divergent dimension from site A, B, C, D and E with respect to length (in meters) as 33.07, 120.89, 22.67, 56.10 and 45.03 respectively, width as 29.05, 12.01, 12.85, 25.50 and 25.66 m respectively while their depth (in meters) were found to be 2.60, 3.40, 2.07, 2.80 and 1.82 m. All type of erosion in the 5 sites were found to be gully erosion. The gully length, width and depth varied considerably along the course of the seasonal river that empties into river Benue. The non-uniformity of the erosion characteristics gives an idea that soil characteristics throughout the gully length in the study area are not uniform.

Site A

Site B

Site C

Site D

Site E
Plate 1: Gully Erosion Sites from Study Area

Table 1: Erosion Characteristics of the Study Area

Location (sites)	Length (m)	Width (m)	Depth (m)	Nature of Erosion
A	33.07	29.05	2.60	Gully
B	120.89	12.01	3.40	Gully
C	22.67	12.85	2.07	Gully
D	56.10	25.50	2.80	Gully
E	45.03	25.66	1.82	Gully

Table 2: Grain Size Analysis of Soil Particles of the Study Area

Site	Position	Sand %	Clay %	Silt %	Textural Class
	Top (0.00-0.86m)	72.08	16.92	11.00	
A	Middle (0.87-1.74m)	75.64	13.00	11.36	
	Bottom (1.75-2.60m)	75.80	12.20	12.00	**Sandy**
	Mean	**74.51**	**14.04**	**11.45**	**loam**
	S.D	**2.10**	**2.53**	**0.51**	
	C.V	**0.03**	**0.18**	**0.04**	
B	Top (0.00-1.13m)	71.80	16.20	12.00	
	Middle (1.13-2.27m)	74.80	14.00	11.20	
	Bottom (2.28-3.40m)	75.08	13.00	11.92	**Sandy**
	Mean	**73.89**	**14.40**	**11.71**	**loam**
	S.D	**1.82**	**1.64**	**0.44**	
	C.V	**0.02**	**0.11**	**0.04**	
C	Top (0.00-0.69m)	70.80	17.00	12.20	
	Middle (0.67-1.38m)	73.36	14.64	12.00	
	Bottom (1.39-2.07m)	75.80	13.20	11.00	
	Mean	**73.32**	**14.94**	**11.73**	**Sandy**
	S.D	**2.50**	**1.92**	**0.64**	**loam**
	C.V	**0.03**	**0.12**	**0.05**	

D	Top (0.00-0.93m)	71.08	16.92	12.00	
	Middle (0.93-1.87m)	74.64	13.06	12.30	
	Bottom (1.88-2.80m)	75.08	13.00	11.92	**Sandy**
	Mean	**73.60**	**14.33**	**12.07**	**loam**
	S.D	**2.19**	**2.25**	**0.20**	
	C.V	**0.03**	**0.16**	**0.02**	
E	Top (0.00-0.61m)	72.80	15.20	12.00	
	Middle (0.62-1.22m)	75.20	12.80	12.00	
	Bottom (1.23-1.82m)	75.08	12.92	12.00	**Sandy**
	Mean	**74.36**	**13.64**	**12.00**	**loam**
	S.D	**1.35**	**1.35**	**0.00**	
	C.V	**0.02**	**0.10**	**0.00**	
	E.S.M	**73.94**	**14.27**	**11.79**	

S.D = standard deviation; C.V = Coefficient of variance, E.S.M = Entire Site Mean

Table 3: Some Physical Properties of the Site Soils

Site	Position	Moisture content (%)	Bulk density (g/cm^3)	Porosity (%)	Permeability cm/s ($\times 10^{-3}$)
	Top (0.00-0.86m)	11.75	1.42	46.40	1.995
A	Middle (0.87-1.74m)	11.65	1.24	53.20	0.246

	Bottom (1.75-2.60m)	11.35	1.40	47.20	1.035
	Mean	**11.58**	**1.41**	**48.93**	**1.092**
	S.D	**0.21**	**0.01**	**3.72**	**0.876**
	C.V	**0.36**	**0.01**	**0.08**	**0.802**
	Top (0.00-1.13m)	12.35	1.40	47.20	0.970
	Middle (1.13-2.27m)	12.45	1.41	46.80	1.022
B	Bottom (2.28-3.40m)	12.20	1.46	44.90	0.357
	Mean	**12.33**	**1.42**	**46.30**	**0.783**
	S.D	**0.13**	**0.03**	**1.22**	**0.370**
	C.V	**0.38**	**0.02**	**0.03**	**0.472**
	Top (0.00-0.69m)	10.45	1.30	50.90	0.308
	Middle (0.67-1.38m)	10.35	1.36	48.70	0.862
	Bottom (1.39-2.07m)	10.20	1.33	49.80	0.924
C	**Mean**	**10.33**	**1.33**	**49.80**	**0.698**
	S.D	**0.13**	**0.03**	**1.10**	**0.339**
	C.V	**0.38**	**0.02**	**0.02**	**0.486**
	Top (0.00-0.93m)	10.85	1.34	49.40	1.109
	Middle (0.93-1.87m)	13.60	1.47	44.50	0.418
	Bottom (1.88-2.80m)	10.30	1.46	44.90	0.912
D	**Mean**	**11.58**	**1.42**	**46.27**	**0.813**
	S.D	**1.77**	**0.07**	**2.72**	**0.356**
	C.V	**1.12**	**0.05**	**0.06**	**0.438**
	Top (0.00-0.61m)	10.40	1.49	43.80	0.296
	Middle (0.62-1.22m)	10.20	1.39	47.50	0.764
	Bottom (1.23-1.82m)	10.90	1.32	50.20	0.271
E	**Mean**	**10.50**	**1.40**	**47.17**	**0.444**
	S.D	**0.36**	**0.09**	**3.21**	**0.278**
	C.V	**0.72**	**0.06**	**0.07**	**0.626**
	E.S.M	**11.26**	**1.40**	**47.70**	**0.766**

S.D = standard deviation; C.V = Coefficient of variance, E.S.M = Entire Site Mean

Table 4: Chemical Parametres of Soils from the Study Sites

Site	Depth	OC %	OM %	N %	P mg/kg	K	Na	Mg Cmol/kg	Ca	EB	EA	CEC	pH
	Top	0.39	0.69	0.31	0.36	0.26	0.23	2.40	2.70	5.59	1.10	6.69	6.08
	Middle	0.24	0.41	0.28	0.32	0.23	0.21	2.30	2.60	5.34	1.12	6.46	6.14
	Bottom	0.26	0.45	0.29	0.30	0.21	0.19	2.00	2.20	4.60	1.00	5.60	6.03
A	**Mean**	**0.30**	**0.52**	**0.29**	**0.33**	**0.23**	**0.21**	**2.23**	**2.50**	**5.18**	**1.07**	**6.25**	**6.08**
	S.D	**0.08**	**0.15**	**0.03**	**0.03**	**0.03**	**0.02**	**0.21**	**0.26**	**0.51**	**0.06**	**0.57**	**0.06**
	C.V	**0.27**	**0.29**	**0.05**	**0.09**	**0.11**	**0.10**	**0.09**	**0.11**	**0.10**	**0.06**	**0.09**	**0.01**
	Top	0.56	0.97	0.40	0.46	0.28	0.26	3.00	3.10	6.64	1.10	7.74	6.12
	Middle	0.28	0.48	0.32	0.42	0.24	0.20	2.20	2.50	5.14	1.00	6.14	6.10
	Bottom	0.25	0.43	0.38	0.33	0.23	0.20	2.10	2.40	4.93	1.13	6.06	6.21
	Mean	**0.36**	**0.63**	**0.33**	**0.40**	**0.25**	**0.22**	**2.43**	**2.67**	**5.57**	**1.08**	**6.65**	**6.14**
B	**S.D**	**0.17**	**0.30**	**0.07**	**0.07**	**0.03**	**0.03**	**0.49**	**0.38**	**0.93**	**0.07**	**0.95**	**0.06**
	C.V	**0.47**	**0.48**	**0.18**	**0.17**	**0.11**	**0.16**	**0.20**	**0.14**	**0.17**	**0.06**	**0.14**	**0.01**
	Top	0.52	0.90	0.42	0.38	0.30	0.26	3.10	3.20	6.86	1.06	7.92	6.26
	Middle	0.32	0.55	0.55	0.34	0.26	0.23	2.60	2.70	5.79	1.04	6.83	6.18
	Bottom	0.30	0.52	0.52	0.31	0.22	0.20	2.30	2.50	5.22	1.10	6.32	6.13
	Mean	**0.38**	**0.66**	**0.34**	**0.34**	**0.26**	**0.23**	**2.67**	**2.80**	**5.96**	**1.07**	**7.02**	**6.19**
	S.D	**0.12**	**0.21**	**0.07**	**0.04**	**0.04**	**0.03**	**0.40**	**0.36**	**0.83**	**0.03**	**0.82**	**0.07**
C	**C.V**	**0.32**	**0.32**	**0.21**	**0.10**	**0.15**	**0.13**	**0.15**	**0.13**	**0.14**	**0.03**	**0.12**	**0.01**
	Top	0.46	0.80	0.36	0.36	0.25	0.22	2.30	2.60	5.37	1.02	6.39	6.09
	Middle	0.27	0.47	0.30	0.32	0.23	0.20	2.20	2.60	5.23	1.00	6.23	6.11
	Bottom	0.28	0.48	0.33	0.36	0.24	0.18	2.00	2.40	4.82	1.03	5.85	6.15
	Mean	**0.34**	**0.58**	**0.33**	**0.35**	**0.24**	**0.20**	**2.17**	**2.53**	**5.14**	**1.02**	**6.16**	**6.12**
	S.D	**0.11**	**0.19**	**0.03**	**0.02**	**0.01**	**0.02**	**0.15**	**0.12**	**0.29**	**0.02**	**0.28**	**0.03**
	C.V	**0.32**	**0.32**	**0.09**	**0.07**	**0.04**	**0.10**	**0.07**	**0.05**	**0.06**	**0.02**	**0.05**	**0.00**
D													
	Top	0.41	0.71	0.38	0.40	0.29	0.24	2.30	2.60	5.43	1.01	6.44	6.19

	Middle	0.31	0.54	0.34	0.37	0.28	0.21	2.00	2.20	4.69	1.00	5.69	6.16
	Bottom	0.28	0.48	0.30	0.31	0.23	0.20	2.00	2.30	4.73	1.10	5.83	6.09
	Mean	**0.33**	**0.58**	**0.34**	**0.36**	**0.27**	**0.22**	**2.10**	**2.37**	**4.95**	**1.04**	**5.99**	**6.15**
	S.D	**0.07**	**0.12**	**0.04**	**0.05**	**0.03**	**0.02**	**0.17**	**0.21**	**0.42**	**0.06**	**0.40**	**0.05**
	C.V	**0.20**	**0.21**	**0.12**	**0.13**	**0.12**	**0.10**	**0.08**	**0.09**	**0.08**	**0.05**	**0.07**	**0.01**
	E.S.M	**0.34**	**0.60**	**0.33**	**0.36**	**0.25**	**0.22**	**2.32**	**2.57**	**5.36**	**1.06**	**6.41**	**6.14**
E													

Key: OC = organic carbon, OM = organic matter, N = nitrogen, P = phosphorus, Na = sodium, K = potassium, Ca = calcium Mg = magnesium,

EB = exchangeable bases, EA = exchangeable acids, CEC = cation exchange capacity, pH = hydrogen potential, S.D = standard deviation;

C.V = Coefficient of variance, E.S.M = Entire Site Mean.

3.2.2 Soil physical properties of the site

Physical properties play an important role in determining soils suitability for agricultural, environmental and engineering uses. The supporting capability, movement, retention and availability of water and nutrients to plants; ease of penetration of roots of crops, and flow of heat and air are directly associated with physical properties of the soil. The soil textures were dominated by sand. Thus, the mean particle size distribution of the soil texture along the five sampled gully sites were found as follows: gully Site (A) has mean soil fraction of 74.51% sand proportion, 14.04% clay and 11.45% silt (Table 3) (Figure 2).

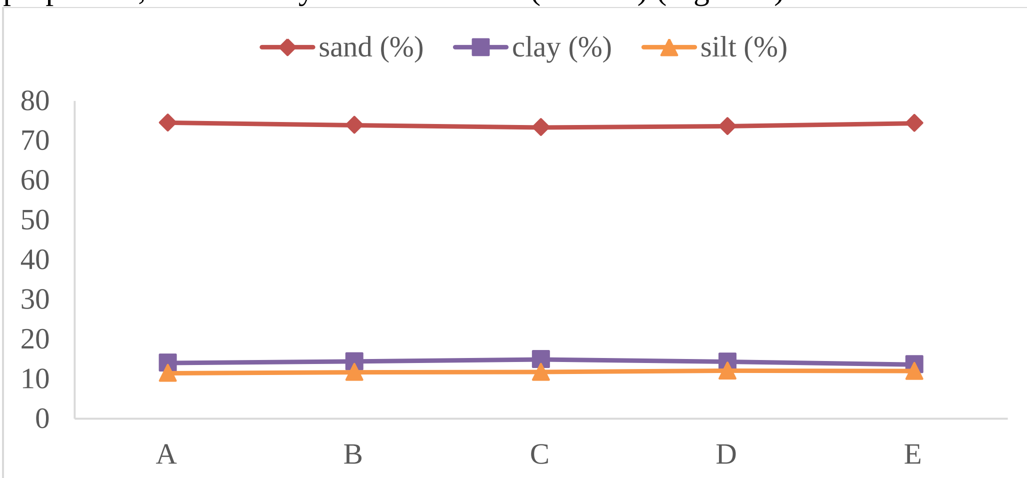

Figure 2: Grain sizes analysis of Soils from the study sites

The standard deviation was 2.10 for sand, 2.53 for clay and 0.51 for silt while coefficient of variance was 0.03 for sand, 0.18 clay and 0.04 for silt. Gully Site (B) showed a 0.44 for silt while coefficient of variance was 0.02 for sand, 0.11 clay and 0.04 for silt. Gully site (C) has mean fraction of 73.32% sand, 14.94% clay and 11.73% silt; standard deviation for same site showed 2.50 for sand, 1.92 for clay and 0.64 for silt while coefficient of variance was 0.03 for sand, 0.12 clay and 0.05 for silt. In gully Site (D) a mean sand proportion of 73.60%, 14.33% clay and 12.07% silt were analyzed. Standard deviation for same site was 2.19 for sand, 2.25 for clay and 0.20 for silt while coefficient of variance was 0.03 for sand, 0.16 clay and 0.02 for silt respectively. In gully site (E) the mean fraction of 74.36% sand, 13.64% clay and 12.00% silt respectively, were found. Standard deviation for same site showed 1.35 for sand, 1.35 for clay and 0.00 for silt while coefficient of variance was 0.02 for sand, 0.10 clay and 0.00 for silt. Particle size distribution, specifically clay and silt fraction have been found to have good relationship with specific surface area, soil compatibility and compressibility,(Danladi and Ray, 2014), all of which affect inherent productivity of the soil.

The implication of these findings is that, with high proportion of sand at the top layer, percolation and infiltration is high, while low infiltration at the bottom layer is due to high proportion of clay content. This might have increase the falling and slumping of gully walls,(Mbaya *et al*, 2012), from the top and middle of the gullies. Moisture contents mean values for the five sampled gully sites (A to E) was 11.58%, 12.33%, 10.33%, 11.58% and 10.50% respectively (Table 3). This implied low values when compared with standard rating tables for moisture content (Table 5), this could have contributed to the long dry season despite the impact of urban waste water that flow into these gully sites.

The results of soil bulk density (g/cm^3), showed that the mean, standard deviation and coefficient of variance of bulk density for the soils is found in gully sites (A – E) are: 1.41, 1.42, 1.33, 1.42 and 1.40 and standard deviation of 0.01, 0.03, 0.03, 0.07 and 0.09 while coefficient of variance are 0.01, 0.02, 0.02, 0.05 and 0.06. This clearly shows the bulk density is low (Table 3).

The result of porosity for gully site A, B, C, D and E ranges between 43% and 51% at the top layer as; the middle layer has 44 to 53% and the bottom layer ranges between 44% to 50% respectively (Table 5) (Danladi and Ray, 2014). Gully sites A and C are the most porous, probably due to the nature of the soil which is sandy loam and degree of sealing surfaces. This finding is within the range of 35-50% and therefore, the soil is porous (Mbaya *et al*, 2012). The implication of this finding is that gully incision and side wall slumping will continue to increase; thereby increasing head ward progression of gullies and destruction of more houses.

The Permeability mean values for the five sampled gully sites were 1.092×10^{-3} cm/s, 0.783×10^{-3} cm/s, 0.698×10^{-3} cm/s, 0.813×10^{-3} cm/s and 0.444×10^{-3} cm/s; the standard deviation had values of 0.876, 0.370, 0.339, 0.356 and 0.278 while the coefficient of variance had values of 0.802, 0.472, 0.486, 0.438 and 0.626 for gully sites A, B, C, D and E respectively as shown in Table 3.

3.2.3 The Soil Chemical properties

All the soil chemical properties analyzed for the different gully sites (A – E), exchangeable bases (EB) exchangeable acids (EA), and cation exchange capacity (CEC), together with computed means, standard deviations(SD) and coefficient of variance(CV) of organic carbon for the soils are as tabulated in Table 4. The results of soil organic carbon (OC) in gully sites (A – E), showed a mean range from 0.30 – 0.38%, SD, 0.07 - 0.17 and CV, 0.20 – 0.47. These implied that the soil contains low organic carbon as shown in Table 5. Therefore, top soils which are removed by erosion inhabit most plant nutrients and organic matter, leaving soils with low nutrient status, poor structure and low water holding capacity. Organic matter content in soils should be in the range of 1.9-3.0% to attain productivity (Ernest, 2016).

The exchangeable bases showed a general increase in mean values from site A- C(5.18, 5.57 and 5.96) downwards into river Benue drain but reduced from site C and D with values as 5.14 and 4.95. The possible variations might be due to mineral constituent of urban waste disposal and the sewage that are washed away into these gully sites. The implication of this findings means that increase in Na can have negative effects on the soil fertility and hence retard the growth of plants such as vertiver, tuff grass and *paniculatu* used for biological control of gully erosion.

These plants are regarded as the most effective method of controlling gully erosion because of its affordability, accessibility and adaptability, this agreed with an earlier findings where it is observed on the effects of exchangeable bases on soils (Danladi and Ray, 2014). The amount of mineral cement (soil binding glue) expressed as the exchangeable bases also showed low correlations with the rate of gully growth. The low mineral cement led to the higher rate of gully advance in the study area.

The cation exchangeable capacity (CEC) is the total capacity of a soil to hold exchangeable cations. The mean values of CEC for the five gully sites range between 5.99 – 7.02. This means that the CEC is medium in the soils of the study area when compared to standard ratings (Figure 3) (Table 5).

Table 5: Standard Rating for Interpreting Levels of Analytical Parametres

Parameter	Low	Medium	High
Ca^{2+} (Cmol Kg^{-1})	< 2.00	2.00 – 5.00	> 5.00
Mg^{2+} (Cmol Kg^{-1})	< 0.30	0.30 – 1.00	> 1.00
K^{+} (Cmol Kg^{-1})	< 0.15	0.15 – 0.30	> 0.30
Na^{2+} (Cmol Kg^{-1})	< 0.10	0.10 – 0.30	> 0.30
CEC (Cmol Kg^{-1})	< 6.00	6.00 – 12.00	> 12.00
OC (%)	< 0.40	0.40 – 1.40	> 1.40
N (%)	< 0.08	0.10 – 0.20	> 0.20
P (mg Kg^{-1})	< 3.00	3.00 – 20.00	> 20.00
OM (%)	< 1.50	1.50 – 2.50	> 2.50
Bulk Density (g/cm^3)	< 1.50	1.50 - 5.00	> 5.00

Key: OM = organic matter, OC = organic carbon, N = nitrogen, P = phosphorus, Na = sodium, K = potassium, Ca = calcium, Mg = magnesium, EB = exchangeable bases, EA = exchangeable acids, CEC = cation exchangeable, pH = hydrogen potential, MC = moisture content

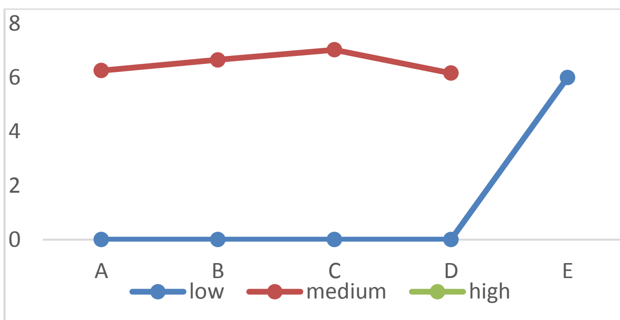

Figure 3: Exchangeable Cations (CEC) of the Study Area

The average pH values for the five gully sites ranged from 6.08 - 6.19) (Table 4). These are slightly acidic (Figure 3). The soil there fore may not be affected by micro-organisms that work on organic matter which enhance the binding of soils to resist erosivity from rainfall and runoff impact. Moreover, the gully sites are within residential area which is not a suitable habitat for micro-organisms(Fifield, 2001; Jon and Jackie; 2015; and IR, 2017).

The results of soil Nitrogen (N) in table 6, showed that the mean, standard deviation and coefficient of variance of organic carbon for the soils is found in gully sites (A – E) are 0.29, 0.33, 0.34, 0.33 and 0.34 (figure 5) and standard deviation of 0.03, 0.07, 0.07, 0.03 and 0.04 while coefficient of variance are 0.05, 0.18, 0.21, 0.09 and 0.12. This clearly shows that the nitrogen content is high.

The Overall pattern of exchangeable bases that is phosphorus (P), potassium (K), sodium (Na), The mean values, standard deviation and coefficient of variance for P, are 0.33, 0.03 and 0.09 (gully site A); 0.40, 0.07 and 0.17 (gully site B); 0.34, 0.04 and 0.10 (gully site C); 0.35, 0.02 and 0.07 (gully site D); and 0.36, 0.05 and 0.13 (gully site E). K has mean values, standard deviation and coefficient of variance of 0.23, 0.03 and 0.11 (gully site A); 0.25, 0.03 and 0.11 (gully site B); 0.26, 0.04 and 0.15 (gully site C); 0.24, 0.01 and 0.04 (gully site D); and 0.27, 0.03 and 0.12 (gully site E), this is shown is Table 5.

The mean values, standard deviation and coefficient of variance for Na are 0.21, 0.02 and 0.10 (gully site A); 0.22, 0.03 and 0.16 (gully site B); 0.23, 0.03 and 0.13 (gully site C); 0.20, 0.02 and 0.10 (gully site D); and 0.22, 0.02 and 0.10 (gully site E), (Table 5). Table 5 shows that, the Mg mean values, standard deviation and coefficient of variance are 2.23, 0.21 and 0.09 (gully site A); 2.43, 0.49 and 0.20 (gully site B); 2.67, 0.40 and 0.15 (gully site C); 2.17, 0.15 and 0.07 (gully site D); and 2.10, 0.17 and 0.08 (gully site E). For Ca, the mean values, standard deviation and coefficient of variance are 2.50, 0.26 and 0.11 (gully site A); 2.67, 0.38 and 0.14 (gully site B); 2.80, 0.36 and 0.13 (gully site C); 2.53, 0.12 and 0.05 (gully site D); and 2.50, 0.21 and 0.09 (gully site E) respectively as shown in Table 5.

The exchangeable bases showed a general increase in mean values for both gully sites. However, this is with respect to K, Na, Mg and Ca. The possible variations might be due to mineral constituent of urban waste disposal and the sewage that are washed away into these gully sites. The implication of these findings to biological control of gully erosion, is that increase in Na can have negative effects on the soil fertility and hence retard the growth of plants such as vertiver, tuff grass and paniculatu which are regarded as the most effective method of controlling gully erosion because of its affordability, accessibility and adaptability.

4. CONCLUSION

The site soil properties were mostly dominated by loosed and very porous sandy constituents with low proportion of silt and clay. The textural class for the entire study site is sandy-loam. The entire site physical properties showed that moisture content and bulk density are low, while porosity was highly permeable. The sandy loam texture was found to be slightly acidic. This means the binding medium within the soils are easily dissolved and washed away. This explains why the gully sites are widening on yearly basis by collapsing from sides. The 4 km length site is within residential areas with complex home settlements devoid of layout. Therefore rainfall characteristics, so8il erodibility, land use, topography has reduced infiltration, leading to higher surface runoff. This has increased deep trenches of gully, destroying valuable lands and houses in the area.

The best mitigation measure to prevent further widening of the gullies which have been destroying houses; is construction of standard concrete drainage channels. Control measures such as land filling, planting of some vegetative shrub cover plants like *Ipomoe Abyssinica*, (Choisy Plant) which grow very fast, mat spread and cover soils against stream bank erosion and lump collapsing.

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