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Table of Contents: Volume 7 Number 5 July 2014

ARTICLES

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Full Length Research Paper

An analysis of some soil properties along gully erosion sites under different land use areas of Gombe Metropolis, Gombe State, Nigeria

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The paper tries to analyse soil properties around three sampled gully erosion sites that cut across different land use in the study area. The aim of the study is to determine the soil physical and chemical properties of the major gully sites cutting across different land use in Gombe metropolis. Data used in this study were derived from soil samples collected from the gully sites and other secondary sources. Three sampled gully profiles were purposively selected for the study. Soil samples were collected at 0-0.30, 0.30-1.0, 1-2, 2-3, 3-4 and 4> meters respectively along the gully wall layers where there are changes in soil types based on the textural characteristics. Soil samples collected were taken to the laboratory for analysis, different soil physical and chemical properties were tested and results obtained. The difference in the soils physical and chemical properties between the three different gully erosion sites were analyzed using the analysis of (variance ANOVA) with the aid of statistical package for social sciences (SPSS) version 16.0. In all the different land use areas studied, the soil is mostly loose and very porous dominated by sandy material with low proportion of silt and clay. Atterberg limits are generally low in all the land use areas which resulted into the weakness of the soil, soil chemical properties and bulk density are low and soil particles are not consolidated, therefore, detached easily when impacted by flood water. This was what facilitates the development of deep and wide gullies found in most areas.

Key words: Soil properties, land use areas, analysis, Gombe metropolis.

INTRODUCTION

Soil erosion remains the world's biggest environmental problem, threatening sustainability of both plant and animal in the world. Over 65% of the soil on earth is said to have displayed degradation phenomena as a result of soil erosion, salinity and desertification, (Abegunde et al., 2006). In a way soil is the most vital

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earth's natural resources. It hosts both animate and inanimate beings. Over three quarters of the world's man-made development are on it. Gully erosion is regarded as the single most important environmental degradation problem in the developing world, (Ananda and Herath, 2003). United nation (UN) convention to combat land degradation (CCD) opines that soil erosion automatically results in reduction or loss of the biological and economic productivity and complexity of terrestrial ecosystems, (Claasssen, 2004).

Soil erosion is also seen as the removal of weathered loose soil material from ground surface with the attendant transport and deposition of sediments elsewhere. In other cases, erosion can be increased when the rate of displacement and removal of the soil from the land surface exceeds its replacement by pedological processes (Ofomata, 2007). It is also defined in terms of detachment of individual's particles of rocks and soil and the transportation of detached particles by the erosive agents of running water and wind, (Okechukwu, 2000). Soil erosion constitutes a national hazard, on which its containment is pre-requisite to national development, (Okagbue and Uma, 1987). Gully erosion is a highly visible form of soil erosion that affects soil productivity, restricts land use and threatens roads, fences and buildings (Bruce 2006).

Soil eroded from the Gullied area can cause siltation of fence-lines, waterways, road culverts, suspended sediments dams and reservoirs which may have attached nutrients and pesticides, which can adversely affect water quality, (Bruce 2006). To prevent soil from being detached, it has to be well aggregated so that the energy of the detaching agent does not exceed the energy of the binding between aggregates, (GECM 2003).

The most cementing material is clay. It is the clay that is most efficient in holding soil particles together. Whether this will be maintained when the soil get wet depends on many factors among which are nature of the clay, exchangeable cations, presence of stabilizing compounds and rate of wetting of the soil. Clays that are largely saturated with calcium and magnesium are generally flocculated and are more value in stabilizing soil aggregates than clays that are predominantly sodium-saturated which consequently detach. Also clays with expanding crystal lattice swell greatly on wetting and therefore have the tendency to break-up soil aggregates, (GECM 2003). In Gombe metropolis, the principal characteristic of soil that has a direct relationship to erosion is the soil texture. The top soils within the metropolis are basically coarse sandy loam. The top soils are also gritty, loose and low non plastic with low bulk density and low shear strength. Under exposed condition with little or no vegetative cover and adverse topography, long dry period and high temperature, the soils with such characteristics are highly susceptible to erosion activities. Much of the areas within the upstream region are highly eroded due to their textural characteristics under high slope.

Study area

Gombe Metropolis is located between latitude 10^0 0'N to 10^0 20'N and longitude 11^0 01'E and 11^0 19'E. It shares common boundary with Akko Local Government Area in the South and West; Yamaltu-Deba to the East and Kwami to the North. It occupied a total land area of about 40Km^2.It is the capital of Gombe State, (Aliyu, 2002) as shown in Figure 1.

Gombe lies in the stretch of the Benue trough which, from the structural point of view is known as Zambuk Ridge area.

The study area consists of two types of soil which correspond to the two geological formations from which they are derived, (Mbaya, 2012). Sandy soil is found in the northwest of the metropolis and is underlain by keri-keri formation from which it was derived. Soil depth varies between 2.0cm as in the area where gullies originated and as deep as 15 to 20cm in some other places, (Orazulike, 1992). The soils are ferruginous which are red in color and contains nodules of ironstone; this soil is marked by deposits of iron oxide pebbles and is loose, very permeable and deficient in plant nutrients, (Mbaya 2012). Clayey soil occurs to the south and southeast of the metropolis and around the Kware River, round railway station. The soil is either derived from the Pindiga formation or clay of Gombe sandstone. The soil is grey and rich in organic matter, and possesses an appreciable shrink-swell capacity as the soils go through periods of drying and wetting.

The pattern of population growth of Gombe town was slow from 1900 to 1952 (300 to 18,500 people) while; from 1964 to 1991 the population growth has increased tremendously from 47,000 to 138,000. However, from the year 1996, when Gombe became the State capital, there was a noticeable sharp increase in population from169, 894 (1996) to 219,946 in 2000 (Tiffen, 2006) and 312,467 in the census 2006 and is projected to reachabout 400,000 in 2010 (NPC, 2006). This population explosion resulted in high demographic pressure on land and consequent developmental processes such asbuilding of houses.

METHODOLOGY

The sources of data as it relates to this study were derived from primary and secondary sources of data. The primary data includes data obtained through laboratory analysis of soil sample collected from gully sites. Secondary data includes relevant literature on the subject matter, which was extracted from published and unpublished sources, textbooks and maps. Variables used for data collection were as follows:

1. Soil physical properties- Particle size, bulk density and moisture

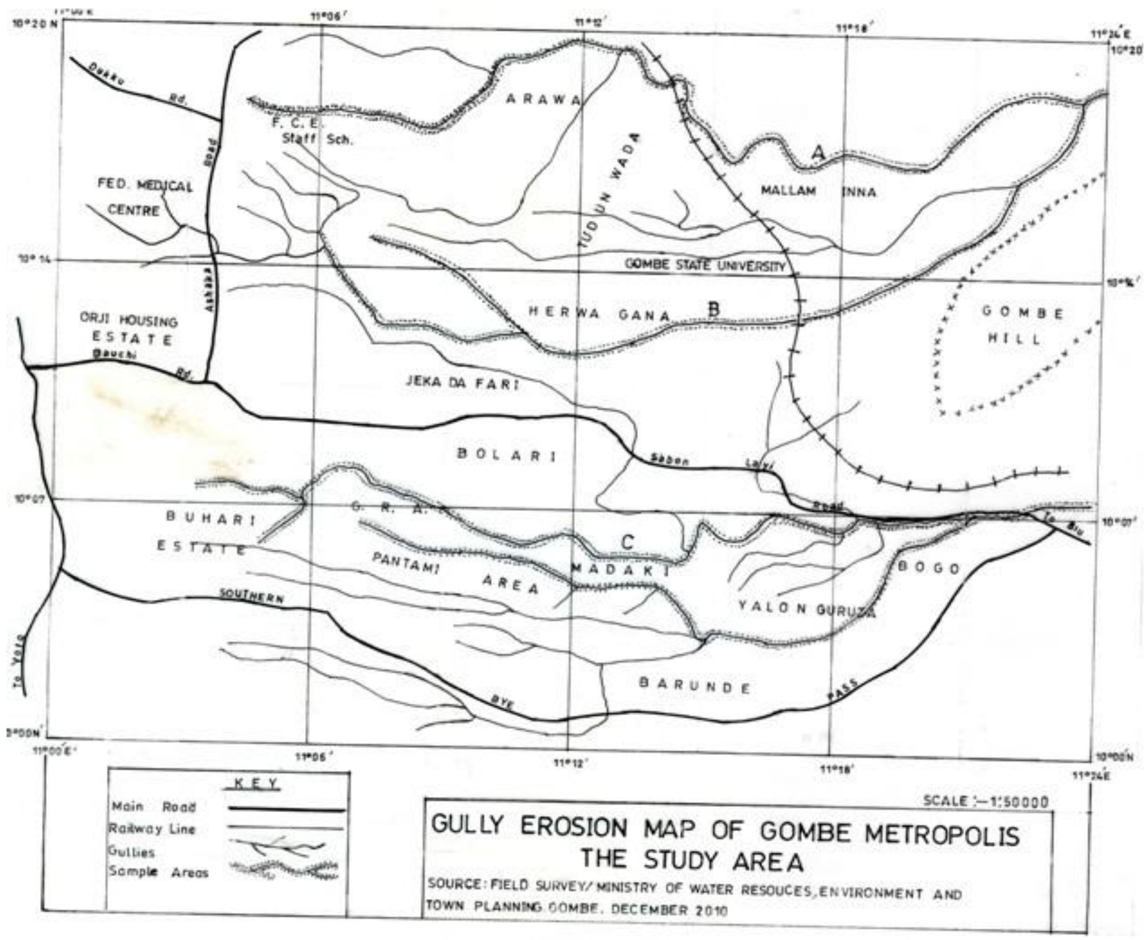

Figure 1. Gully erosion map of Gombe metropolis

content of soil.

2. Soil chemical properties - Organic matter content, soil pH, Cation exchange capacity (CEC), calcium (ca), magnesium (Mg), sodium (Na) and potassium (K),
3. Geologic- rock /porosity, permeability and Atterberg limits, etc.

Two procedures were adopted in the data collection process. These included:

1. Field work involving collection of soil samples along the selected gully erosion sites, using soil auger, handheld shovel, and polythene bags, masking tape.
2. Laboratory analysis of soil samples.

Soil sampling

Soil samples were collected at each point of gully morphological properties measured. This is to determine the susceptibility of soil to gully erosion. Soil samples were collected along gully side walls to the toe of the gully. A 30 m linen tape were stretched along gully wall layer profile to the toe of the gully, samples were collected at 0 to 0.30metre, 0.30 to1m, 1 to 2m, 2 to 3 , 3 to 4m, and > 4metres where there arechanges in soil types based on textural characteristics along the gully wall of the profile. A total of thirty six soil samples were collected and kept in polythene bags for laboratory analysis. Augur and Hand held shovel was used to collect the samples. All the collected samples were labeled and named after the gully erosion site where the samples are to be collected and will be taken to Laboratory for analysis. As shown in Figure 2.

Laboratory analyses of soil samples

Soil samples collected were taken to laboratory for analysis, soil particle distribution, chemical properties (organic matter, soil pH, exchangeable cations), bulk density, moisture content, permeability and Atterberg limits (Liquid limit, Plasticity limit and plasticity index) were tested using different measuring instrument in the laboratory and results obtained. The difference in the soils physical properties between the different gully erosions were analyzed using the analysis of variance (ANOVA) with the aid of statistical package for social sciences version 16.0.

RESULT AND DISCUSSION

The results of this research work were presented and discussed below. The result obtained were discussed

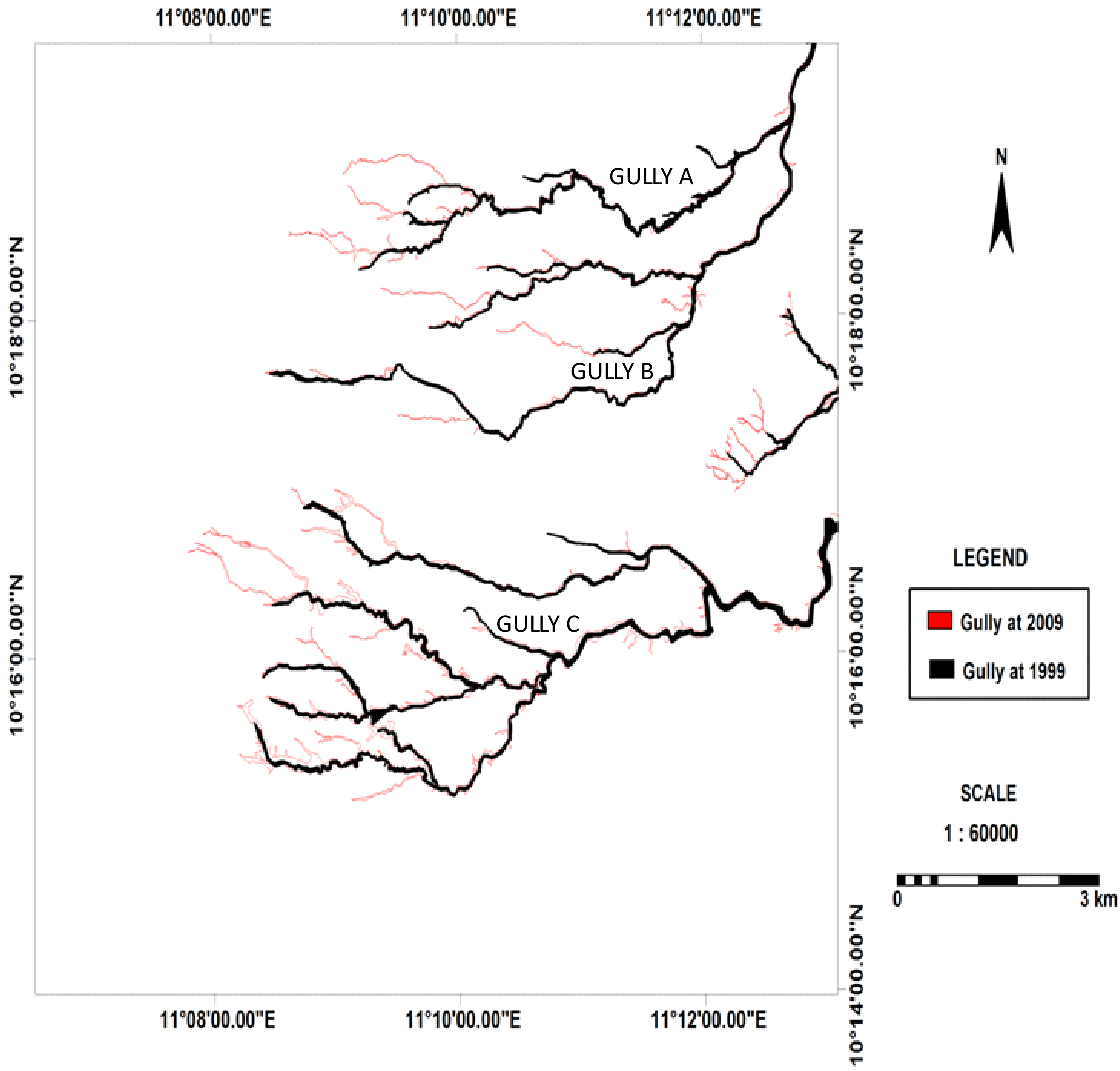

Figure 2. Classified gully density of the study area.
Source: NRSC 2013.

based on the different land use areas studied, which include residential, educational, commercial/industrial and agricultural land uses, this is in order to provide an area by area analysis.

The land use areas

The residential land use represent the largest land use in Gombe metropolis consisting of the highest number of kilometers covered by gully erosion. It consists of the build up areas occupied by residential. Majority of the gully erosion sites within the metropolis spread across the residential areas. While the educational land use on the other hand consist of schools and other educational institutions within the metropolis, the number of gullies within this land use are few, covering only a small portion of the land use area, the gullies are specifically found within the Federal College of Education Gombe as well as Gombe State University and Government Arabic College Gombe. The commercial/industrial land use area consist of different commercial and industrial areas as well as different points where commercial activities are taking place within the metropolis, it consist of gully erosion that run from Idi ground through PZ to Kagarawal. The agricultural land use consist of areas where agri-cultural activities are practiced, especially farming activities, this mainly exist at the outskirt of the metropolis around bypass area where the branch of Wuro-shi'e gully is found. As shown in Figure 3.

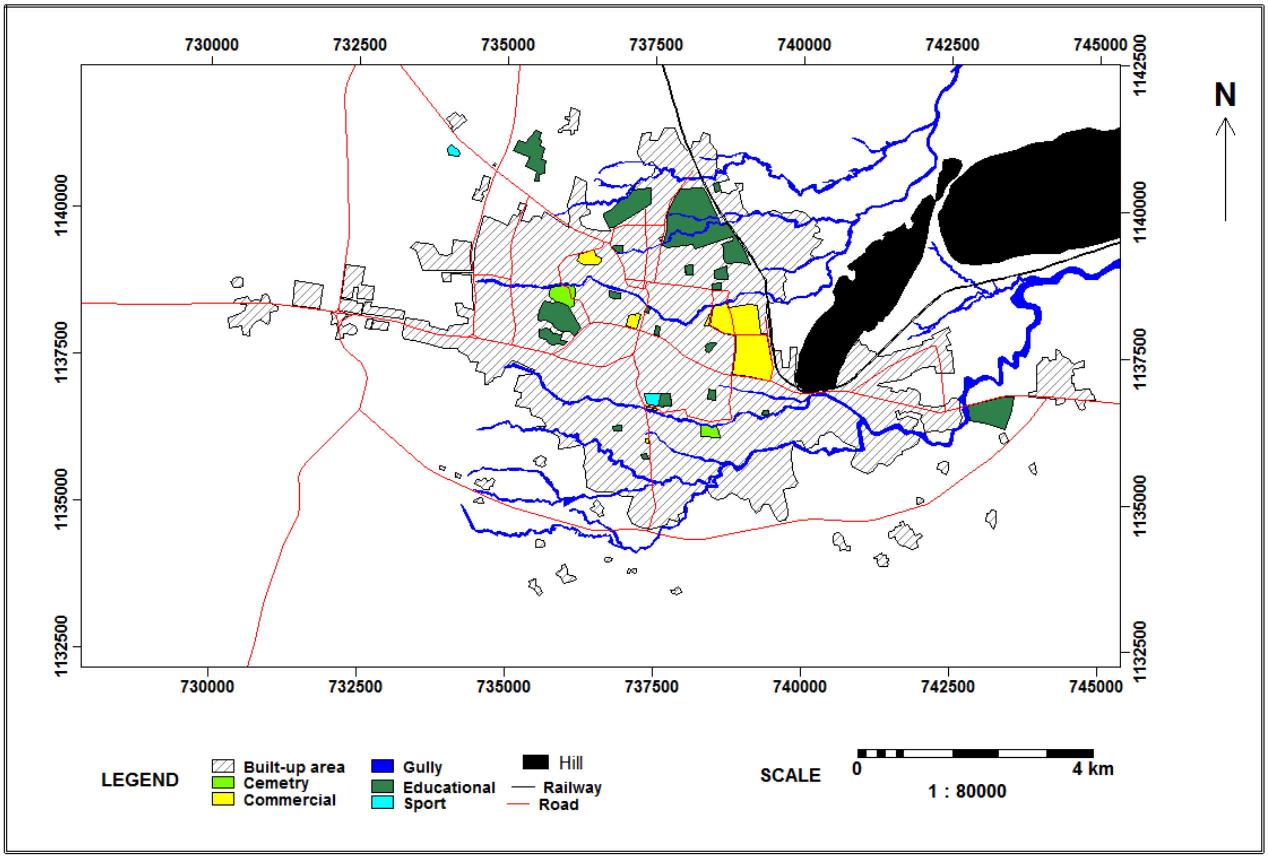

Figure 3. Classified land use image of Gombe
Source. NRSC, 2013.

Soils physical properties of the study area

The table 1 present result of some of the soil physical properties obtained in different land use areas studied. The mean particle size distributions of the soil along the three sampled gully wall layers in the residential area are presented in table 1. Gully site A, (FCE—Arawa-M/Innna-U/Uku) has the mean sand proportion of 78.5%, with coefficient of variation (C.V) of 1.14%. ; Gully site B also showed a mean sand proportion of 73.5% and gully site C further showed similar mean sand proportion of 74%. The mean proportion of silt contents for gully sites A is 5.5%, Gully B has mean silt proportions of 5.0%, and gully site C has mean silt proportions of 3.2%. The mean proportions of clay content among the three gully sites are almost similar. Gully site A, has mean clay proportion of 13%, Gully site B 17 % and gully site C 18.8% respectively. The soils particle size distribution therefore, is dominated by sand with low proportion of silt and clay in all the sampled gullies within the residential land use. Also, most of the gully floors are characterized by sandy clayey regolith.

The soil particle distributions for the gullies within the Educational land use are also presented in table 1. Gully site A has a mean sand proportion of 68.05%, B has 64.70% and C has 67.04%. The mean proportion of sand obtained from the sampled gullies under Educational land use is slightly lower than that obtained under Residential land use, this might be due to the control effort made with the use of vegetation, which may results in reducing the percentage of sand and increasing the percentage of clay and silt along the gullies. The mean proportion of silt particles within the sampled gullies A, B, and C were 5.83%, 8.0%, and 11.5% respectively. The mean values for clay particles are also presented in table 1, with gully sites A having mean proportion of 26.5%, B has 23.4% and C has the mean value of 25.8%. This suggests that, the soils within the two land use areas (Residential and Educational) have fairly pore spaces. This was supported by the Carter and Gregorich, (2008) rating of sandy surface porosity of which soils range from 35 to 50%, whereas finer textured soil ranges from 40 to 60% and compact sub soils may have as little as 25 to 30% total pore space.

The soil particle distribution for the commercial and agricultural land use were also studied and presented in

Table 1. Soil physical properties

Land use area	Soil Property	Gully site A (FCE-Arawa-M/Inna-U/Uku)			Gully site B (Fed.lowcost-B/Yero-herwagana-idi-u/uku)			Gully site C (Old GRA- Gabukka-Barunde-Madaki-Bogo-Doma)		
		Mean	SD	C.V	Mean	SD	C.V	Mean	SD	C.V
Residential	Sand	78.5	9.2	1.14	73.5	7.7	1.23	74.0	4.5	1.27
	Silt	5.5	1.2	14.9	5.0	2.2	13.9	3.2	2.2	18.5
	Clay	13.0	7.3	4.93	17.0	6.7	4.21	18.8	6.9	3.89
	Bulk Density	2.0	0.2	49.5	1.8	0.2	50.0	1.6	0.3	52.6
	Moisture Content	10.5	0.6	9.01	10.6	0.6	8.92	9.8	0.6	9.6
Educational	Sand	68.05	9.1	1.16	64.70	4.6	1.32	67.04	5.0	1.16
	Silt	5.83	1.0	2.25	8.0	2.1	9.90	11.5	3.8	6.5
	Clay	36.5	7.8	2.25	33.4	6.6	3.0	35.8	4.9	1.90
	Bulk density	2.2	0.3	40.0	1.9	0.2	47.6	2.0	0.2	49.5
	Moisture content	10.9	0.7	8.62	10.7	0.6	8.92	9.8	0.6	9.6
Commercial	Sand	Gully site A IS absent within commercial land use , therefore no data obtained.			78.05	9.0	1.11	Gully site C IS absent within commercial land use , therefore no data obtained.		
	Silt				5.8	1.3	14.7			
	Clay				14.0	7.3	4.90			
	Bulk density				1.1	0.5	39.5			
	Moisture content				8.0	0.4	9.0			
Agricultural	Sand	Gully site A and B are absent within agricultural land use land use , therefore no data obtained						63.21	8.0	1.13
	Silt							14.5	4.2	6.9
	Clay							12.0	6.7	4.0
	Bulk density							2.0	0.2	51.0
	Moisture content							10.8	0.6	8.75

table 1.

However, the commercial and agricultural land use areas are not affected by all the three major gullies sampled for this study. Commercial land use is only affected by gully site B which passes through it, while agricultural land use is affected only by gully site C at Wuro-shi'e. Table 1 also revealed that the mean sandy value obtained in the Idi-kagarawal gully site under the commercial land use was 78.05%, and a mean value of 63.21% was obtained from the Wuro-shi'e gully under Agricultural land use. The mean values for silt and clay particles obtained under commercial and Industrial land use are 5.8 and 14.0% respectively. Another value was obtained for the mean values of silt and clay under agricultural land use as indicated by table 1 is 12.0 and 14.5% respectively. The percentage silt and clay are higher in the agricultural land use than that of the commercial land use due to the presence of different species of plants grown in the area.

Textural classification of soil in the study area

The major textural classes of soil are defined by the percentage of sand, silt and clay obtained from the soil particle analysis. A mixture of sand, silt and clays particles that exhibit the properties of those separate in about equal proportions are considered as loamy, Brady and Ray (1999). However, a loam in which sand is dominant is classified sandy loam, sand and loamy sands are dominated by the properties of sand which comprises at least 70% of the material by weight and less than 15% of the material is clay, Brady and Ray (1999).

The soil particle suggested sandy loam soil as the dominance soil of the study area thereby agreed with Nyle C. Brady's above statement, this is because the soils in the area have about an average of 70% sand proportion in the different land use areas studied. The soil texture in the area appears to be similar to that obtained in Mubi and environs which has sandy loam as textural class. The textural classification of the study area as shown in table 1 indicates the dominance of sand in the soil with an average of 70% in proportion. This indicate the soil erosion in the area may be as a result of the function of soil erodability, this is supported by Gosh and Maji (2011), which shows that the medium and coarse particle that are more easily detached from the soil mass, therefore more erodible.

Soil bulk density

The mean soil bulk density for the three sampled gullies within the residential land use revealed 2.0%, 1.8g/cm^3, and 1.6g/cm^3 for gully sites A, B and C respectively. This may be attributed to the different areas that they exist within the residential areas. The mean values for bulk density are also obtained from the gullies under Educational land use which has 2.2g/cm^3, 1.9g/cm^3 and 2.0g/cm^3 for gully A, B and C respectively. The bulk density mean values obtained in both the commercial and agricultural land use are 1.1g/cm^3 and 2.0g/cm^3 respectively, with 0.5, 39.5 and 0.2, 51.0 as standard deviation and cumulative values for commercial/industrial and that of agricultural land uses respectively. This low bulk density could be attributed to soil compaction and soil structural degradation. Again the alternate increases of the bulk density within the gully depth with the associated compaction may lead to overburdening of the soil materials on the top which may slide upon horizontal pressure.

Soil moisture content

Moisture content values for the three sampled gully sites within Residential and Educational land use are also shown in table 1. The table showed gully site A, has a mean value of 10.5 g/cm^3; Gully site B has 10.6 g/cm^3 and gully site C has 10.3 g/cm^3 for Residential land use and 10.9g/cm^3, 10.7g/cm^3 and 9.8g/cm^3 for Educational land use respectively.

The moisture content means values for the commercial/ industrial land use is 8.0g/cm^3 with 0.4 and 9.0 as standard deviation and cumulative value respectively. Other values were also obtained for agricultural land use with the mean moisture content value found to be 10.8g/cm^3 with standard deviation and cumulative value of 0.6 and 8.75 respectively, table 1.

The high values of moisture content in all the sample gullies are probably as a result of urban waste water that flow into some of these gullies, (Mbaya et al 2012) and presence of vegetation used in some gullies for control effort especially within educational land use. The descriptive data in table 1 was further subjected to ANOVA test to establish whether there is significance difference in the soils physical properties between the gully sites selected. The result showed no differences ($P>0.05$).This implies that the proportions of sand, silt, clay, bulk density and moisture content for the sites under the four land use areas studied are almost similar. The possible reasons for this might be attributed to the nature of the soil, geology and land use of the study area.

The result indicates that gully erosion is more severe in the residential land use and commercial land use areas of Gombe metropolis because the soils are dominated by sandy materials, which makes it more susceptible and consequent increase in gully erosion more especially the depths. This findings agreed with those of others studied by Yakubu, (2004), Ofomata, (2007) and Rahab, (2008) and Mbaya (2012) who indicate that the dominance of sand proportion in the Nigeria savanna soils has accelerate gully erosion.

Soil atterberg limit, shear strength and aggregate stability

Table 2 presents the result of soil analysis foratterberg limit, shear strength, and aggregate stability of all the different land use areas studied, the result is presented and discussed to show the level of these variables in the area. Table 2 presents the results of Atterberg limits (liquid limit, plasticity limit and plasticity index) obtained in the study area. Liquid and plasticity limits were measured and were used to obtain the plasticity index, which is a measure of the plasticity of the soil.

The mean liquid limits (LL) for gully site A, B, and C, are 27.4, 26.5, and 27.0% respectively in the residential land use, and 28.9, 27.0, and 27.1 for the three sampled gullies under educational land use. Different values were also obtained for the commercial and agricultural land use with the mean values for LL as 27.0 and 28.0% respectively. The analysis further revealed no significance difference in LL ($P>0.05$) among the sampled gullies. The mean plasticity limits (PL) for gully site A, is 22.4%, gully site B have mean values of 21.5% and gully site C have mean values of 27.0 % for all the three sampled gullies in the residential area. The mean values for plasticity limits of the sampled gullies in the educational land use are 22.7, 22.5 and 22.9% for gully A, B and C respectively. The mean PL values as presented in table 2 for commercial and agricultural land use areas obtained were 24.0 and 21.5% respectively.

The mean values for plasticity index (PI) as shown in table 2 for residential land use are 3.5, 4.0 and 4.1% for the sampled gullies A, B and C respectively. Separate values were obtained for the sampled gullies under educational land use with gully A having 5.9, B has 4.5 and C has 4.2%. While the mean values for PI are 5.0 and 4.5 for the commercial/industrial and agricultural land use respectively. The results in table 2 show low values for atterberg limit in all the land use areas under studied; this explained the weakness of the soils and frequent removal of the gully surfaces.

The results of permeability test in table 2 revealed that the mean values for gully site A, B and C in the residential area are $3.8x10^{-3}$, 2.4x $10-^{3}$ and $1.9x10^{-3}$ respectively, and the mean values for sampled gullies A,B and C in the educational land use are $3.0x10^{-3}$, $2.5x10^{-3}2.1x10^{-3}$ respectively, the mean values obtained for commercial/industrial and agricultural land use areas as presented in table 8 are 3.6 x 10^{-3}cm/sec and 2.0 x 10^{-3}cm/sec respectively. No significance difference ($P>0.05$) among the sampled gullies were observed. The result of porosity test for gully site A, B and C for the residential

Table 2. Soil Atterberg limits and aggregate stability test

Land use area	Soil Property	Gully site A (FCE-Arawa-M/Inna-U/Uku)			Gully site B (Fed.Lowcost-Bubayero-Herwagana-Idi-Uku)			Gully site C (OldGRA-Gabukka-Barunde-Madaki-Bogo-Doma)		
		Mean	SD	C.V%	Mean	SD	C.V%	Mean	SD	C.V
Residential	LL %	27.4	0.8	3.5	26.5	1.1	3.6	27.0	1.0	0.3
	PL%	22.4	1.4	3.8	21.5	0.6	3.5	22.9	0.8	0.2
	PI%	4.9	1.1	16.6	4.5	0.5	20	4.1	0.6	0.03
	PM (Cm/sec)	$3.8x10^{-3}$	2.2	20	$2.4x10^{-3}$	1.4	26.3	$1.9x10^{-3}$	1.2	0.02
	AS	6.0	0.6	15.2	6.5	0.8	13.6	6	0.7	0.04
	Porosity (%)	45.5	0.0	2.2	44	0.00	2.2	43.0	1.28	0.5
Educational	LL %	28.9	0.7	3.4	27.0	1.0	3.7	27.1	1.0	0.3
	PL %	22.7	1.3	4.0	22.5	0.5	4.3	22.9	0.7	0.2
	PI %	5.9	1.2	14.0	4.5	0.5	2.0	4.2	0.6	0.03
	PM (Cm/sec)	$6.0x10^{-3}$	2.2	2.0	$2.4x10^{-3}$	1.4	26.3	$1.9x10^{-3}$	1.2	0.02
	AS	6.55	0.6	14	5.5	0.6	15.6	5	0.7	0.03
	Porosity (%)	46.5	0.0	2.2	43	0.00	2.3	51.0	1.26	0.7
Commercial	LL%	Gully site A IS absent within commercial land use , therefore no data obtained			27.0	1.8	2.5	Gully site C IS absent within commercial land use , therefore no data obtained		
	PL%				24.0	1.4	3.3			
	PI%				5.0	1.1	15.8			
	PM cm/sec				$3.6x10^{-3}$	2.2	15			
	AS				5.0	0.8	15.0			
	Porosity				47.0	0.3	2.4			
Agricultural	LL%	Gully site A and B are absent within agricultural land use , therefore no data obtained						28.0	1.1	2.6
	PL%							21.5	0.6	3.0
	PI%							4.5	1.0	20.2
	PMcm/sec							$2.0x10^{-3}$	1.4	26.0
	AS							6.5	1.0	14.0
	Porosity %							40	0.4	2.2

LL- Liquid limit, PL – Plasticity limit PI - Plasticity index, AS- Aggregate Stability PM- Permeability, AIF- Angle of internal friction.

land use are 45.5, 44.0 and 43.0% respectively as shown in table 2, the educational land use has mean porosity values of 46.5, 43.0 and 51.0% for gully A, B and C respectively. While that of commercial/industrial and agricultural land uses were 47.0 and 40.0% respectively.The degree of porosity shows the ease to which water can percolate and disintegrate the structure of the soils.

Soil chemical properties of the study area

Table 3 presented results of some of the soils chemical properties analyzed for the four different land use areas studied, (pH, organic matter content and exchangeable cations). These are some of the important chemical properties of soil when assessing gully erosion. Soil pH value indicates whether the soil is acidic or alkaline. The average pH values for the three gully sites in the residential land use are 6.2, 5.7 and 5.6 for gully site A, B, and C respectively; the mean values for the gullies in the educational land use are 5.7, 6.0, and 5.2 for A, B, and C respectively. Another mean values of soil pH were obtained under the gully wall layers of commercial/ industrial and agricultural land use with 5.2 and 5.5 respectively. This implied that the soil in the study area is moderately acidic. However, there was no significance difference (P> 0.05) between the different gullies site studied. The implication of this finding is that the soil of the study area may not be affected by micro-organisms that work on organic matter which might enhance the binding of soils to resists erosivity of rainfall and runoff impact.

The overall pattern of exchangeable Ca, Mg and K for all gully site A, B and C in the residential land use were shown. The mean values for Ca are 5.3 (gully site A), 8.3(gully site B) and 7.5 (gully site C); K has mean values of 4.7 (gully site A), 2.2 (gully site B) and 2.1(gully site C); and Mg mean values are between 2.5, 2.8 and 2.6 for gully site A, B and C respectively. They showed a general

Table 3. Soils chemical properties

Land use area	Soil Property	Gully site A (FCE-Arawa-M/Inna-U/Uku)			Gully site B (Fed.lowcost-Bubayero-Herwagana-Idi-Uku)			Gully site C (OldGRA-Gabukka-Barunde-Madaki-Bogo-Doma)		
		Mean	SD	C.V	Mean	SD	C.V	Mean	SD	C.V
Residential	pH	6.2	0.36	60.5	5.7	0.65	15.7	5.6	0.41	16.6
	%OM	0.8	0.01	123.4	0.8	0.32	89.3	1.3	0.00	76.9
	Ca	5.3	0.34	39.3	8.2	0.20	11.9	9.5	0.21	10.3
	Na	0.8	0.01	123.4	0.8	0.00	125.0	1.0	0.01	99.0
	K	4.7	0.35	19.8	2.2	0.01	45.2	1.4	0.01	71.3
	Mg	2.5	0.24	36.5	2.8	0.25	32.7	2.6	0.22	35.5
	P	19	1.70	4.80	32	5.99	2.60	20.5	1.2	4.6
Educational	pH	4.5	0.32	20.8	5.3	0.61	16.9	4.2	0.40	22.6
	%OM	0.8	0.01	123.4	0.7	0.01	140.8	0.6	0.00	166.6
	Ca	5.5	0.32	17.2	9.5	0.44	10.1	10.5	0.40	0.17
	Na	1.0	0.01	99.0	0.9	0.00	111.1	0.9	0.00	111
	K	2.6	0.20	35.7	1.0	0.01	99.0	1.5	0.00	66.6
	Mg	3.0	0.31	30.2	3.8	0.24	24.8	3.4	0.31	3.5
	P	12	1.67	7.30	20	5.98	3.87	18.5	1.2	3.9
Commercial	pH	Gully site A IS absent within commercial land use , therefore no data obtained			5.2	0.36	60.5	Gully site C IS absent within commercial land use , therefore no data obtained		
	%OM				0.81	0.01	123.4			
	Ca				4.9	0.34	39.3			
	Na				0.8	0.03	121.0			
	K				2.7	0.35	19.8			
	Mg				2.2	0.24	36.5			
	P				16.0	1.82	4.83			
Agricultural	pH	Gully site A and B are absent within agricultural land use , therefore no data obtained						5.5	0.65	15.7
	%OM							1.9	0.32	89.3
	Ca							9.52	0.20	11.9
	Na							0.94	0.01	125.0
	K							3.2	0.01	45.2
	Mg							3.8	0.33	32.7
	P							32	24.4 2	5.72

OM- Organic matter ,Na – Sodium K – Potassium Mg – Magnesium, P- Phosphorus

increase in mean values for both soil layers. However, ANOVA, revealed significant differences in soil layers among the sample gully sites (P>0.05). This is with respect to Ca, K, and Mg. table 4.4 also presented the result of the exchangeable Ca, Mg and K, with the mean values of 4.9, 2.2, and 2.7 respectively for commercial/ industrial land use and 9.52, 3.8 and 3.2 for agricultural land use respectively.

The pattern of exchangeable Ca, Mg and K for all gully site A, B and C in the educational land use are almost similar to that of residential land use . The mean values for Ca as presented by table 9 are 5.5, 9.5, and 10.5for gully A, B, and C respectively. K has mean values of 2.6 (gully site A), 1.0, (gully site B) and 1.5 (gully site C); and Mg mean values are 3.0, 3.8 and 3.4 also for gully site A, B and C respectively. On the whole the valley bottom soils were more enriched with the basic elements, while the top or middle layer recorded the lowest mean values. This may be explained in terms of the relative steepness of the gully walls and hence downward of the basic elements and subsequent accumulation at the valley floor.

Exchangeable Na on the other hand showed an irregular increase and decreased in mean values of the gully walls. The mean values for gully site A, B and C in the residential area are 0.8, 0.8, and 1.0 respectively. On the other hand, the mean values for the gullies in the educational land use are 1.0 for Gully A, 0.9 for Gully B, and 0.9 also for Gully C. different mean values were also obtained in the gullies under commercial/industrial and agricultural land use. The mean value of 0.8 with standard deviation of 0.03 and commulative value of 121.0 were obtained under commercial/industrial, while the mean values of 0.94 with SD of 0.01 and CV of 125.0 were obtained under agricultural land use. Analysis of variance showed significant differences (P>0.05) among the sampled gully site. 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 to biological control of gully erosion, is that increased in Na can have negative effects on the soil fertility and hence retard the growth of plants such as vertiver grass and paniculatu/ Pitadeniastrumafricanum which are regarded as the most effective method of controlling gully erosion because of its affordability, accessibility and adaptability. The results of soil organic matter content (OMC) in table 3 showed that the mean values of gully site A, B and C was low in both residential and educational land use s. The overall pattern of variation of organic matter content, revealed a downward increases in the organic contents. However, there was significant differences at the top and bottom layers of the gully walls (P>0.05). The possible causes of these differences might be attributed to leaching of the organic matter down the valley floors of the gully sites. Table 3 also shows the mean values for organic matter content with 0.81% for gully under commercial/industrial land use and 1.94% for agricultural land use.

The results of soil phosphorus test (Table 3) showed mean values from Gully A to C. Gully site A, B and C in the residential land use have mean values of 19, 32ppm and 20.5ppm, respectively; and the mean values for Gullies A, B and C in the educational and use as 12, 20, and 18.5 respectively. Another mean values were obtained for gully layers under commercial and agricultural land use , the mean values as presented by table 12 is 16.0 ppm with SD of 1.82 and CV of 4.83, the table also shows the value for agricultural land use with 32ppm, and the SD of 24.2 and CV of 5.72. However, analysis of variance showed significant differences between the sampled gully walls. This value is low, and translates low phosphorus in the soil. These findings agreed with Ayuba (1992), who observed that, the Nigerian savanna is characterized by low phosphorus. In general, the amount of mineral cement expressed as the oxides of Ca, Mg, Na and K shows low correlations with rate of gully growth: the smaller the amount of cement, the greater the rate of gully advance.

CONCLUSION

Gully erosion menace has been on increase and advancing at alarming rates over the past few decades in Gombe metropolis, causing untold hardships, misery and loss of houses, lives and other properties worth millions of naira.

In all the three sampled gullies studied cutting across different land use areas the soil is mostly loose and very porous. Atterberg limits, soil chemical properties, bulk density are low and the soil particles are not consolidated, therefore this detached easily when impacted by flood water. This was what facilitates the development of deep and wide gullies found in most areas. This explain why some of the gully control effort by government fail, because of their in ability to properly study the soil around the gullies before controlling it. Solving erosion problem must be based on scientific and engineering data of associated variables such as soil, rainfall data, runoff etc.

Conflict of Interests

The authors have not declared any conflict of interests.

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Socio-economic effect of gully erosion on land use in Gombe Metropolis, Gombe State, Nigeria

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Gully erosion is one of the severe environmental problems facing Gombe metropolis. It threatens urban infrastructure, properties, lives and the physical growth of the town. This article assesses the socio-economic effect of gully erosion in Gombe metropolis. The aim of the study was to assess the socio-economic effect of gully erosion on land use in Gombe metropolis. Data used in this study were derived from field administration of questionnaire and focus group discussion. Three sampled gully profiles cutting across different land use areas were purposively selected for the study. They were referred as Gully A, transect FCE-Arawa-M/Inna-U/Uku Gully site; Gully profile B, transect Fed.lowcost-B/Yero-Idi-Herwagana-Idi-U/Uku Gully site and Gully profile C, transect Old/GRA-Gabukka-Barunde-Madaki-Bogo-Doma. From each gully profiles, 10% of the population around the gully site was used as population sample administering the total of 207 questionnaires in all the three gully sites under different landuse areas. Results obtained through questionnaires and focus group discussions was analysed, using simple percentage presented in different tables and discussed.The results indicated that several buildings, farmlands/plots and other properties worth millions of naira as well as both human and animal lives were lost due to effect of gully erosion in the study area.

Key words: Socioeconomic, gully erosion, land use, Gombe metropolis.

INTRODUCTION

Soil erosion is widely recognized as a major environmental and agricultural problem affecting many parts of the world. Estimates suggest that, each year, as much as 75 billion ton of soil are removed from the land by wind and soil erosion, with most of it coming from agricultural land (Pimentel et al., 1995). While the rates at which soil erosion occurs vary over time between different locations, it has intensified in recent years,

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causing great concern in developing countries. The "on-site" impacts of soil erosion are commonly associated with shortages of arable land that is capable of supporting agricultural production, common in Asia and Africa, but also in Europe. While 0.5/ha of arable land per capita is deemed necessary to ensure people are given a diverse diet, Pimentel et al. (1995) in (Mbaya 2013) estimates that about one-half of this is currently available. The short and medium term consequences for developing countries are evidenced by the widespread prevalence of food shortages and malnutrition. Within the next forty years, he further predicts that the effects of soil erosion and rapid population’s growth could mean that a little over a quarter of the arable land per capita deemed necessary to ensure people diverse diets, will be available.

There are also downstream or "off-site" impacts of soil erosion. For instance, eroded sediments can be deposited in reservoirs, reducing hydro-electric generation and the flow of water supplies for irrigation and residential uses (Mbaya 2013). The use of large amounts of fertilizers, pesticides and irrigation to help off-set the deleterious effects of soil erosion have the potential to create pollution and health problems, as well as destroying natural habitats and this contribute to high energy consumption and unsustainable agricultural systems (Pimentel et al., 1995) in (Mbaya. 2013).

The World Bank (1990) in (Mbaya, 2013) recognized three main environmental problems facing Nigeria: soil degradationand loss, water contamination and deforestation. Gullyerosion contributes to each of the three main problems and causes damage with an annual cost to the nation, estimated at $100 million in1990.

Unfortunately, the situation has not changed significantly in 2010. As at 1997, there were 5,700 gully erosion sites nationwide (Agagu, 2009) in (Mbaya 2013). This figure has certainly increased. For example in 2009, the World Bank Country report on Nigeria still listed gully erosion as one the top five major hazards threatening the Nigerian environment. Numerous new gullies have emerged and many of old gullies have grown rapidly to disaster levels. Accelerated erosion with its effects on agriculture in Nigeria is well documented, but the fact that several Nigerian towns facing gully erosion is far less well known. Urban gully erosion affects only 18,517km2, representing only 2% of the total area of Nigeria (Titilola et al., 2008) and so tends to be ignored in the literature. However, the area of land affected by gullies is not the sole criterion for estimating the damage they inflict on the national economy. The value of the lands they destroy and the cost of protective measures should be considered.

Gully erosion in towns, destroys valuable land, communications facilities, lives and buildings. This involves expensive control measures and requires more research work. The expansion of concreted surfaces in towns, heightened volume and velocity of runoff that is generated have tended to make many Nigerian towns increasingly susceptible to gully formation. When most of the available land in an urban area is built-up, increased pressure on land might lead to extension of urban land use to the stream channels, flood plains and restriction of streams to artificial channels .This is the situation being experienced in Gombe town. Gully erosion is a major problem in Gombe town since 1980s; however, the situation is getting worse annually, since Gombe town assumed the status of state capital. The infrastructural development coupled with demographic increase, have no doubt heightened the problems of gully erosion in the state capital.

Residents of Gombe town have expressed concern over accelerated erosion rates. These concerns addresses not only the loss of personal property, but also that gully erosion is causing functional and structural damage to infrastructures such as culvert outlets and roads within the stream channels as well as other public and private structures along the channel. The Federal and State Governments have attempted to solve the problem through numerous contracts awarded for gully erosion project at some key sites in Gombe town. However, the economic practicalities and engineering control measures has not met people’s expectation, owing to lack of adequate information on the gully morphological parameters. Therefore, solving the gully erosion problem in Gombe town requires concerted research efforts. The main aim of this research was to study the socio-economic effect of the gully system of study area.

Socio-economic effects of gully erosion: A global perspective

Gully erosion increases loss of available land for agricultural purposes and increases labour cost. The main on-site impact of erosion is the reduction in soil quality which results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of many eroded soils. In affluent areas of the world, accelerated water erosion’s on-site effects upon agricultural soils can be mitigated by increased use of artificial fertilizers; however, this is not an option for much of the earth’s population, (Mortlock, 2005).

He further stressed that, erosion’s removal of the upper horizons of the soil results in a reduction in soil quality that is, a diminution of the soil’s suitability for agriculture or other vegetation. This is because the eroded upper horizons tend to be the most nutrient-rich. Also, because the finest constituents of eroded soil tend to be transported furthest, eroded soils become preferentially depleted of their finer fraction over time; this often reduces their water-holding capacity. In other words, “Erosion removes the cream of the soil”. Loss of soil quality is a long-term problem; globally, soil erosion's most serious impact may be its threat to the long-term sustainability of agricultural productivity, which results from the 'on-site' damage which it causes. Crops are particularly reliant on the upper horizons of the soil, which are the most vulnerable to erosion by water and wind. In this sense, erosion removes 'the cream of the soil'. Agricultural tillage also redistributes soil, resulting in thinner soils on topographically convex areas within a field.Jeje and Agu (1990) showed that top soils affected by severe sheet wash in Ejiba area of Kwara state have suffered serious loss of their clay aggregates, organic carbon and exchangeable cation, Ca, K, Mg and N in comparison with other local soils not so affected. In addition, they are also characterized by very low infiltration rate, and very low water holding capacity. This loss in soil fertility leads to steady decrease in crop yields and this complicates the anxiety of the local farmers over their economic wellbeing. The loss of land for cultivation is a serious social and economic consequence of soil erosion, given a situation where farming is the main occupation of majority of the people.

At the Agulu-Nanka gully complex, over 1,000 hectares of land have been lost to the gullies and the modest estimate for the expansion of the gullies is at least 1% per annum, (Ofomata, 2007). Of the World’s 13,500 million ha of land not under water, 22% is suitable for cropping but only 10% is currently farmed, losses in arable land have increased over the past ten years to a current rate of 7 to 10 million ha per year as a result of erosion, FAO (2007). Apart from the loss in soil fertility and continuous diminutions of cultivable land, both of which really translate to the farmer’s property, there is additional loss of property, in the common sense of usage of the word and which here includes loss of homes, household property and farm crops.

In Araromi Rubber plantation about 10% of trees have been uprooted, while gullying is handicapping toping operations and increasing production cost, as the gullies have in some cases cut across some motorable roads. This often leads to diversions that have only hastened the growth of gullies. At Uyo, gullies have rendered a sizeable proportion of the land and most of the roads useless, valuable properties have also been lost, especially to old station gully and along Eka street gully, (Ofomata, 2007). In October 1988; at Enugu-Nanka, similar landslides occurred in the same area in August 1989, causing wide spread damages to homes and farm crops. Over 0.25 hectares of farm crops was cutoff and sent down to the bottom of the gully following a serious landslide, Ofomata (2007).

Gully expansion and head ward originations have led to the disruption of many roads. The gullies succeed in cutting off some roads, which causes great inconvenience to the people, several other examples exist, but the case of NgwoAgu, at Agulu and Ogbu must be known, where the busy road that leads from Agulu to Eke Ogbu market has been cut to the middle, (Ofomata 2007). These examples can be multiplied over the country, and the social implication of such a consequence as disruption of roads is well understood. The failure of the intervention schemes also causes severe psychological stress and physical damages on individuals and communities. In south eastern Nigeria, for example, as a results of landslides that accompany the flooding, houses were washed into the gullies that develop sometimes with their inhabitants, they further stated that as intervention measures fail and gully erosion expands, communication and power lines were broken, churches and schools collapse, roads are washed off, water schemes are damaged and lines are lost. Also farmland and farm produce are washed off while families are displaced and drives away as refugees. The entire social and economic lives of communities are totally disrupted, Egboka (2007).

When these happen as they often do each rainy and dry season, the internally displaced people became desperate and demoralized. Their problems are compounded because they cannot individually or even as communities solve the severe problems created by the disruptive erosion, they become further impoverished in their attempt to survive with meager resources. Even when this is done, minimal positive results are achieved and new channel and gully sites are invariably initiated. Another important economic consequence of erosion is in the financial cost of ameliorative efforts which takes money from other vital sectors of the economy. Governments, at both the federal and state levels, have shown concern and taken a number of steps to combat the problems of soil erosion in the country. A national soil conservation committee was set up in 1978 (under the auspices of Federal Department of Agricultural Land Resources) and submitted its preliminary report in 1979. After 1980, billions of naira has been spent on control and management of gully erosion in Nigeria. Egboka (2004), said an estimate of the total initial funds that can be made available by the Federal Government to Southeastern states to combat the ecological problems to make the desired impact is conservatively put at about 628 million dollars at the first instance.

The revenue act sets aside 1% of the federal account for ameliorating ecological problems throughout the country. The government also established a National committee on Ecological problems to advise government on policies and projects for effectively combating ecological problems including erosion. Such resources would have been used for other social amenities.

Study Area

Gombe Metropolis, the capital of Gombe State (Aliyu, 2012). Figure 1 is located between latitude 10^0 0’N to 10^0

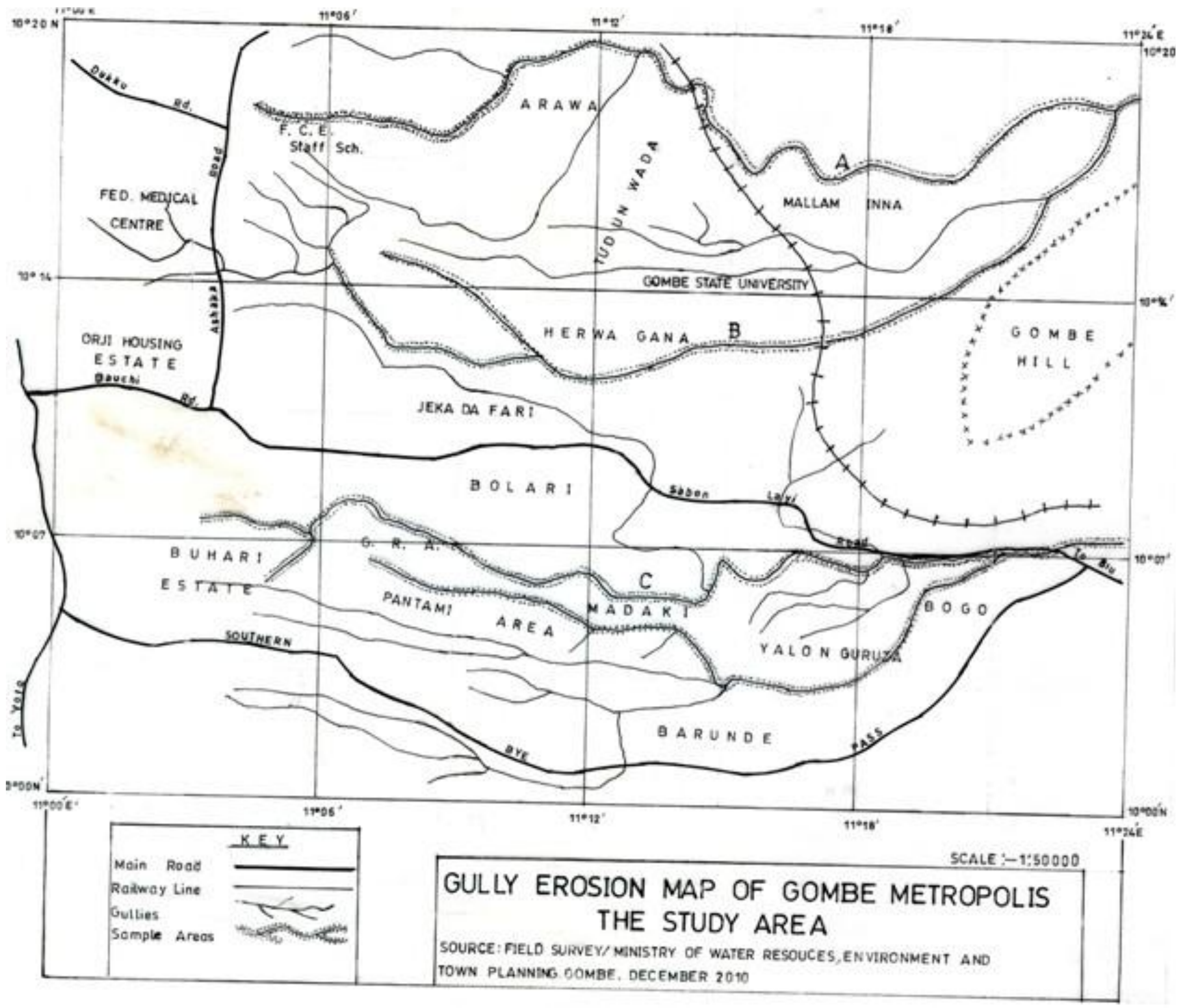

Figure 1. Gully erosion map of Gombe metropolis

20'N and longitude 11^0 01'E and 11^0 19'E. With a total area of about 40km^2, it is bordered by Akko Local Government Area in the South and West,Yamaltu-Deba to the East and Kwami to the North. Gombe lies in the stretch of the Benue trough which, the structural point of view is known as Zambuk Ridge area.

The spatial and temporal analysis of Gombe's urban layout showed centrifugal growth, building densification and urban layout modification (Balzerek et al., 2003).This development resulted in the unification of the traditional settlement and the peri- urban areas in the1990s to formed a single urban body, which reached the size of 30km2 in 2000 (Balzerek et al., 2003). This expansion, has led to an urban intrusion into the peri urban environs far beyond the original town borders and is followed by a significant change in landuse which has increased the sealed surface thereby reducing the infiltration rate of rain water (Balzerek et al., 2003). The pattern of population growth of Gombe town wasslow from 1900 to 1952 (300 to 18,500 people) while, from 1964 to 1991 the population growth has increased tremendously from 47,000 to 138,000. However, from the year 1996, when Gombe became the State capital, there was a noticeable sharp increase in population from169, 894 (1996) to 219,946 in 2000 (Tiffen, 2006) and 312,467 in the census 2006 and is projected to reachabout 400,000 in 2010 (NPC, 2007). This population explosion resulted in high demographic pressure on land and consequent developmental processes such as building of houses.

METHODOLOGY

The sources of data as it relates to this study were derived from primary and secondary sources of data. The primary data includes data obtained through questionnaire and focus group discussion with the people living around the gully sites. Secondary data

Table 1. Houses and persons affected by gullies

Landuse	Houses destroyed	%	Person(s) affected	Buildings/shops at risk
Residential	239	100	20121	1249
Commercial/industrial	Nil	0	0	452
Educational	Nil	0	0	15
Agricultural	Nil	0	4	0
Total	239	100	20125	1701

includes relevant literature on the subject matter, which was extracted from published and unpublished sources, textbooks, maps, photographic and satellite imagery of the study area. Several gully erosion sites exist within the different land use in the study area. But the major ones which cut across different land use areas within the metropolis are three. These include:

1. FCE-Arawa-M/Inna-U/Uku Gully site (labeled gully A)
2. Fed.lowcost-B/Yero-Idi-Herwagana-Idi-U/Uku Gully site (labeled gully B)
3. Old/GRA-Gabukka-Barunde-Madaki-Bogo-Doma Gully site (labeled gully C)

For the number of questionnaires administered to the people residing around each gully erosion area, 10% of the population is considered as the sampling size for the different landuse areas within the metropolis, random sampling techniques were used to determine the individual respondent.

RESULT AND DISCUSSION

Table 1 present the results of the questionnaires administered to household heads within the vicinity of the sampled gully sites as well as direct observation within the landuse areas on socio -economic effects of gully erosion. The findings showed that gully erosion has over the years destroyed houses, roads and bridges/ culverts, loss of lives and depreciation of land values. For most families in Gombe metropolis, land has remained a traditionally inheritable commodity, and is passed on from one generation to another. The problem with gully erosion is it's difficult to fully reclaim if lost. Once it takes hold, it becomes almost a lost battle to reverse the degradation. Thus, when it occurs to any land, that precious piece of land is permanently lost to the owner(s) or depreciates in its value when selling or when rent out.

Table 1, showed a total of 239 houses were destroyed within the land use areas with a total of 20125 people displaced within the period of fifteen years from 1996 to 2011. This implied average loss of 16 houses or 128 persons per year within the period of fifteen years from 1996 to 2011.Table 1, also shows that 239 houses/ buildings were destroyed in the residential land use by gully erosion with no single house destroyed by gullies within the other three land use areas (that is; commercial, educational and agricultural).Table 1 also shows the total of 20121 people that lives in the houses/buildings destroyed by gullies are directly affected within the residential land use, but a total of four persons were affected by gullies in the agricultural land use and none identified to be directly affected in the other two land use areas (commercial and educational). Cracking and falling of buildings and other physical structures into gully sites are common features in the erosion prone areas within the study area. Shown in Plate 1.

Table 1 further revealed that about a total of 1701 houses located at the distance of 100m from the sampled gullies within the different land use areas are at risk of losing their houses or lives to gully erosion in the near future if no control measures are taken, with the total of 1249 houses at risk in the residential land use, 452 and 15 houses are at risk in the commercial and educational land use respectively. The gully erosion has also destroyed many roads, culverts and bridges in the different land use areas investigated. Table 2 showed that a total of 19 roads both tarred and untarred and 22 culverts and bridges that provide easy transportation of people and goods were destroyed.

Table 2, also shows that 11 out of 22 culverts destroyed are within residential land use representing 50% of the total culverts/bridges destroyed by gullies, 7 out of 22 culverts destroyed are in the commercial land use while 4 out of 22 culverts are in the educational landuse representing 31.8 and 18.2% respectively. Table 2, also shows numbers of plots/farms destroyed, it shows that 103 plots/farms were destroyed by gully erosion within the different land use area with residential land use having 64 plots destroyed, commercial land use 31 plots and educational having 4,b representing 30.1% for residential, 62.1% for commercial and 3.9%, as well as3.9% for educational and agricultural land use respectively.

Table 3, revealed that the total of about 15 persons died within all the land use areas studied as a result of gully erosion within a period of 15 years from 1996 to 2011 with 8, 5, 2 people in the residential, commercial and educational land use respectively, representing 53.3, 33.3 and 13.3% for residential, commercial and educational land use respectively. A total of about 40 animals are also said to be lost as a result of collapsed buildings and gully walls from 1996 to 2011 (15 years) with residential, commercial/industrial and educational land use having 15, 15 and 10 animals respectively. The

Plate 1. View part of houses destroyed at Herwagana by gully erosion
Source. Fieldwork, 2011.

Table 2. Culverts, road and undeveloped lands affected

Landuse area	No of Culverts/bridges destroyed	%	No of plots/farms destroyed	%	No of roads destroyed	%
Residential	4	18.2	31	30.1	6	31.5
Commercial/industrial	7	31.8	64	62.1	8	42.1
Educational	11	50	4	3.9	5	26.3
Agricultural	0	0	4	3.9	0	0
Total	22	100	103	100	19	100

Table 3. Human and animal lives lost

Landuse area	No of lives lost	%	No of animal lost	%
Residential	8	53.3	15	37.5
Commercial/industrial	5	33.3	15	37.5
Educational	2	13.3	10	25
Agricultural	0	0	0	0
Total	15	99.9	40	100

above findings was also supported by Belzerek (2003), which states that floods and streams/gullies undercut buildings near the banks of gullies, they destroy roads and drown people and animals. Some of these gullies measure shoulder widths of 50 to 75m and reach depths between 3.5 and 18m.

Causes of gully erosion in the study area

The causes of gully erosion in the study area are numerous, some of which are identified both through questionnaire administration and physical observation shown in Plate 2.

Table 4, shows the causes of gully erosion in the study area as observed by the respondents. The respondents mentioned the improper erosion control, poor drainage, construction along the water ways, as well as indiscriminate clearing of vegetation. In the residential land use, 43.7% of the respondents attributed the causes of gully erosion in the study area to improper erosion control, 24.3% in the educational land use also believed on

Table 4. Causes of gully erosion in the area

Causes	Improper Erosion Control		Poor Drainage		Construction along water ways		Clearing of vegetation		Land escavation	
Variables	**Fq**	**%**	**fq**	**%**	**Fq**	**%**	**fq**	**%**	**fq**	**%**
Residential	45	43.7	30	41.7	8	20.5	28	50.8	05	62.5
Educational	25	24.3	18	25	20	51.3	14	25.5	-	00
Commercial	27	26.2	20	27.7	11	28.2	09	16.4	02	25
Agricultural	06	5.8	04	5.6	-	00	04	7.3	01	12.5
Total	103	100	72	100	39	100	55	100	08	100

Note. fq= frequency

Plate 2. Bello Sabo Kudi road/ bridge destroyed by flooding in 2004.
Source. Field work, 2011

in the control of gully erosion within the metropolis, these wrong control techniques adversely contributed to the widening of existed gullies in the study area. For example, sometimes only simple stone walls are used, this do not prevent the gully extension at all, but are undermined and subsequently flushed away during a hazardous event like the large scale flooding event of 2004 in Gombe metropolis. Interms of poor drainage, 41.7% of the respondents within the residential land use mentioned poor drainage as one of the major causes of gully erosion in the area, in the educational land use, 25% recognized poor drainage while it is 27.8 and 5.6% in the commercial and agricultural land use respectively.

The poor drainage facility as observed by the respondents within the metropolis has led to the formation of several gullies in the area, also as a result of inability of the existed drainage to contain much volume of run-off as a result of rainfall. Table 4 shows that 20.5, 51.3, and 28.2% of the respondents identified construction and dumping of refuse along water ways as one of the major causes of gully erosion in the residential, educational and commercial land use respectively, while it was 0% in the agricultural land use. The respondents observed that people construct buildings and dump refuse along waterways. This makes the water to flow with full force thereby expanding the existing gullies.

The indiscriminate clearing of vegetation in the study area, has been identified as one of the major causes of gully erosion by the respondents, table 4 shows that 50.9% in the residential area believed that clearing of

Table 5. Measures taken by the Communities/Individuals

Variables	Fq	%	Fq	%	Fq	%	Fq	%
Landuse	**Sand Bag**	**%**	**Tree Planting**	**%**	**Stone embkmt**	**%**	**Others**	**%**
Residential	31	41.9	38	52	10	28.6	9	9.6
Educational	21	28.4	15	20.5	12	34.3	20	43.5
Comm./Ind.	18	24.3	16	21.9	13	37.1	17	36.9
Agriculture	4	5.4	4	5.5	0	0	0	0
TOTAL	74	100	69	100	35	100	46	100

Note. fq= frequency.

vegetation is one of the problems that led to gully erosion in the area, while 25.5, 16.4 and 7.3% in the educational, commercial agricultural land use areas respectively also identified clearing of vegetation as one of the causes of gully erosion. Table 4 also shows 62.5% of the respondents in the residential land use as those that identified indiscriminate sand escavation as one of the causes of gullies in the area, while it is 25% in the commercial land use and 12.5% of the respondents in the agricultural land use, none of the respondents in the educational land use identified sand escavation as one of the major causes.

The indiscriminate sand excavation at different point in the study area for construction activities provide a major source of concern, as it lead to the development of several gullies especially at the western part of the metropolis where kerri-kerri formation dominate.

Measures of preventing and/or controlling gully erosion

Table 5, present the results of the interview conducted on the effort of community on the prevention and controlling gully erosion in the study area. The respondents mentioned the use of sand bag, tree planting, stone embankments, use of other vegetation such as vetiver grass in gully erosion control. In the residential land use for instance, 41.9% of the respondents used sand bags in their control and 52% used tree planting while 10 and 9% of the respondents used stone embankment and other local methods respectively.

In the educational land use on the other hand, 28.4% used sand bag, 20.5% used tree planting, 37.1% used stone wall while 43.5% used other methods such as planting of vegetation along the gully wall layers such as vertiver grass. In the commercial/industrial landuse, the respondents interviewed had 25.7% for sand bag, 21.9% for tree planting and 37.1, 36.9% for stone wall and other method respectively. While agricultural landuse for sand bag and tree planting are 5.4 and 5.5% respectively.

Government’s intervention effort

Recently, the Gombe state governments have earmarked and awarded the contract for the continuation of gully erosion control within the metropolis, for instance, the sum of 1,250,000 dollars was earmarked for the control of gully erosion from Shongo Housing Estate through Central Bank of Nigeria main office and another from Pantami Market to GGSS Doma at the cost of 987,500 dollars only. The ecological fund office also earmarked the sum of 439 million naira for the control of Bogo-BCGA gully erosion. Previous studies conducted on the Gombe township erosion control shows that, the total length of gully within the metropolis is about 121.5km, out of this only 5.6km in length have been controlled, while 7.62km have been partially controlled, leaving about 107.3km still uncontrolled, SEEDS (2006).

CONCLUSION

Gully erosion has been on increase and advancing at alarming rates over the past few decades in Gombe metropolis, causing untold hardships, misery, loss of houses, lives and other properties worth millions of naira. As human population within the study area rises, more land is cleared of its available natural vegetation and replaced with impervious surfaces leading to low infiltration-runoff ratio. The situation is further worsened by rise in value of urban land due to population increase. These force people to erect buildings on floodplains, consequently increasing the magnitude and frequency of gully erosion in response to high storm water runoff and channel concentration, this led to more destruction of lives and properties as observed in the study area. There exist no significant structures of protection instituted by government for victims of the menace. The affected population is almost left to cope with and manage the disaster on their own.

Solving the problem of gully erosion in Gombe metropolis therefore; requires adequate funding, committed political will (not lip-service) and well-articulated sustainable policies. The development of an effective gully erosion control/prevention management programme must be based on accurate scientific and engineering data on the size of the gullies, the engineering geological properties of the soils, the characteristics (volume/velocity) of the surface run-off and the associated human activities. The implementation of the adopted remedial management programme, must be holistic in approach, (preferably on watershed basis), with well co-ordinated participation of government, private sector and the affected communities.

Conflict of Interests

The authors have not declared any conflict of interests.

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