Aspects of Gully Erosion in Benin City, Edo State, Nigeria.

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Abstract
This research work examines aspects of gully erosion in Benin City with a view to ascertaining the nature of soils in gullies subsoil using 2nd cemetery gully as a case study and to find reasons why soils are easily washed off by runoff. Therefore, the objectives considered were: moisture content of soils, the degree of firmness of physical state of the soils and particles size analysis. In order to meet these objectives, laboratory test was carried out for Atterberg Limits or consistency limits, In Situ moisture content of soil and particles size analysis using sieve and sedimentation test. The results showed that the soil type is Acid clay soil and silty gravel sand using the British Standard Sieve Sizes. Recommendations were made for the need to protect the top soils from storm water and runoff, regulation of land use types, the use of manual brakes should be encouraged especially where money for the control of soil erosion is lacking amongst others.
Keywords: Soils, Gully erosion, Benin City

1. Introduction

Most research in soils are usually carried out using soil catena with the laboratory analysis of its physical and chemical properties. In Nigeria, those that have worked on soils are: Doyne and Watson 1933; Vine 1949; Dupreez 1949; Moss 1965; Ologe 1972, Pruski and Nearing 2002; Odemerho and Sada 2002; Aziegbe 2005; Ofomata 2009, amongst others. Soils and landforms are closely related to the extent that they depend on the same factors like climate, relief, vegetation, parent material and time (Aziegbe, 2005). As a result, soil scientists especially pedologist and geomorphologists have developed profile models that help to explain the spatial differences and interrelationships among soil erosion, transportation, deposition and soil properties.

Where gullies are, runoff easily remove vast amount of soils on the ground surface in Benin City. Gully erosion is when a rill channel becomes much deeper and wider to forms a gully. Gully erosion occurs when erosion is concentrated on definite channels. When the channels eventually become deepened and steep sided, they are referred to as gullies. In Benin City, gully erosion is basically rill erosion on a much larger scale. It has become very much severe and is depleting the various landscape and land use patterns of Benin City. Gully erosion normally results when rill erosion is not checked and controlled in a particular area. The runoff gathers greater force from insequent and subsequent channels as water moves down slope to deepen the channel continually to produce gullies.

The geotechnical properties of soils are usually divided into engineering properties and index properties. The main engineering properties of soils are permeability, compressibility and shear strength. On the other hand, the index properties are those properties that are indicative of engineering properties. Most of the test carried out to determine index properties of soils are referred to as classification test such as Atterberg Limit test, Specific gravity test, Hydrometer test and Sieve Analysis.

For the purpose of this study, soil analysis was carried out using samples taken in gullies of 2nd cemetery road, Benin City. This 2nd cemetery road gully slopes from Ehenede and Agho end to a depression pondage, about 585 meters in length which has made continuous access and use of this road impossible. This is also one of the most devastated gullies at Uzebu quarters. There is no existing drain on this road and most of the buildings around the depression pondage area are at the point of being submerged by sediments carried by runoff. It is against this background that the nature of soils in the gully is being considered for analysis. This is done in order to ascertain the reasons why gullies are easily being created by runoff.

2. The Study Area

Benin City lies between latitudes $6^0 20'$ and $6^0 58'$ North and between longitudes $5^0 35'$ and $6^0 41'$ East of the Greenwich Meridian. The area lies within the Sub Humid Tropical Region. Simply because of its location, Benin City has a temperature of about 27^0c and an annual rainfall of over 2000mm (Eseigbe, Omofonmwan and Kadiri, 2007). It has two seasons, the wet and the dry seasons. The wet season last from March to October while the dry season is from November to February with scanty rainfall. These seasons are controlled by the position of the Inter-Tropical Discontinuities (ITD) whose movement is reflected in the corresponding shifts with the rain belt (Aziegbe, 2000). The wet season begins in March and reaches its first maximum in July and the second is September. Both maxima are separated by a brief spell referred to as "August Break". In any case, rainfall is experienced throughout the year with December and January being the driest as shown in Table 1. The tropical maritime air mass and the tropical continental air mass are the prevailing winds in the area. The maritime air mass dominates the area through a greater part of the year. The monthly rainfall in Benin is higher in the months of May, June, July, September and October as shown in Table 1. The highest amount of rainfall is recorded in the month of September 1998 with monthly rainfall of 499.5. This is followed by the month of July in 2002 with monthly rainfall of 437.3. Other monthly rainfalls are as expressed in Table 1.

Table 1. Monthly Rainfalls in Benin City, Nigeria, From 1997-2010 in Millimeters.

Months	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	41.6	9.5	29.8	5.8	11.0	0.0	49.3	35.2	0.0	22.5	0.0	1.2	5.2	27.0
February	0.0	20.0	54.4	11.8	1.0	27.8	26.9	13.5	15.7	10.5	104.2	4.6	6.8	22.0
March	114.1	50.4	89.1	61.9	152.3	133.6	68.3	55.3	167.2	61.3	56.2	72.4	151.2	96.4
April	108.6	129.8	166.6	153.1	237.7	209.8	250.8	106.4	114.4	158.0	197.7	187.2	127.2	216.7
May	280.1	143.2	262.1	92.4	182.1	201.5	181.2	323.4	138.9	246.8	246.2	208.6	210.6	281.2
June	315.0	177.5	236.0	434.9	251.9	356.6	162.9	355.7	292.7	172.5	380.9	360.7	234.4	232.2
July	161.5	246.6	241.5	220.8	253.2	437.3	155.0	214.3	406.8	289.0	284.7	297.5	266.5	371.4
August	152.0	59.9	172.9	241.9	139.8	308.5	170.1	298.6	80.9	335.9	171.4	186.4	264.4	287.4
September	232.1	499.5	399.3	399.3	343.3	180.9	313.5	251.1	177.3	347.4	256.0	266.6	342.2	351.7
October	253.3	251.0	282.5	282.5	114.4	237.1	293.7	247.0	267.2	304.5	285.0	270.1	281.2	263.1
November	47.8	28.0	23.8	23.8	18.9	42.7	31.3	28.3	33.9	24.7	37.1	32.4	19.1	26.7
December	0.9	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	6.4
Total	1706.9	1565.4	1957.7	1912.3	1809.5	2135.8	1703.0	1928.8	1595	1972.9	2036.5	1891.7	1909.8	2177.8

Nigerian Meteorological Agency, Benin City 2011

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Benin City is built on a nearly undulating low-lying surface. The eastern edge of it is tilted towards the Ikpoba River that drains the eastern portion of the city while the Western edge slopes gently towards Ogba stream that drains the Western portion of the City. Benin City is drained by a series of entrenched river and small streams such as Ikpoba River, Ogba Stream and Osse stream. Many depositional land forms results especially flood pains characterized with point bar, islets,levees, backswamps and channel filling, alluvial fan and Delta.

Benin City is underlain by sedimentary formation of the Miocene-Pleistocene age often referred to as the Benin formation. The local relief in the City is 91 meters above sea level. A topographical map of the city on a scale of 1,27,778 produced by Balasha – Jalon consultants shows that the city contained 15 local depressions which may have been formed during the arching in the Neogene of the lower Tertiary Beds (Odemerho, 1988).

The relationship between vegetation and soil erosion and between cultivation and soil loss are well known (Osterkamp and Toy, 1997). It has been realized that forest soils become more erodible when put under cultivation. Changes in vegetation cover bring about direct and indirect changes in the soil environment which leads to an alteration in the structural organization of the soil. The tropical rainforest vegetation is noticeable in the area of study. The predominant vegetation here is the moist deciduous forest which is rich in timber resource. In the area of study, the different land use types have resulted into deforestation of all kinds which have contributed to the soils inability to resist erosion by water.

3. Aim and Objectives

The aim of this research work is to examine the rate of soil erosion and the creation of gullies in 2nd cemetery road, Benin City. The specific objectives include:

(a) To determine the moisture content of soils in the exposed gully of 2nd cemetery;
(b) determine the degree of firmness or physical state of the soils; and
(c) to carry out the particle size analysis of the soils in 2nd cemetery gully.

These will enable us to know the characteristics of soil that encourage the creation of gullies in Benin City

4. Research Methods

For the purpose of this research work and to be able to meet the objectives for which this research work is carried out, soil analysis was carried out in one of the gullies in 2nd cemetery road, Benin City. The analysis was based on the sub-soil samples collected since the top soils have already been washed off by surface runoff. The soil sample was obtained from erosion ravaged gully of 2nd cemetery road, Benin City. Among the laboratory test carried out on the soil sample are In Situ moisture content determination, Atterberg limits test or consistency test and particle size analysis of soil.

The In Situ moisture content of soil is the percentage of water present expressed as a percentage of dry weight of the soil. This method is mostly used in soil classification and gives an indication of the soil type. The water content of a soil sample can be determined by oven dry method, sand bath method, Torsional balance method, Alcohol method, calcium carbide method and speedy moisture tester method. The oven dry method was used here to determine the In Situ moisture content.

The Atterberg Limits or consistency limits is used to determine the degree of firmness of fine-grained soils and is described by such terms as soft, medium and hard. The water content at which the soil changes from one state to another is known as consistency Limits or Atterberg Limits (Arora, 2005). These consistency limits are liquid, plastic and shrinkage limits.

On the other hand, the particle size analysis or mechanical analysis is a method of separation of soils into different fractions based on the particle sizes. It expresses quantitatively the proportions by mass of various sizes of particles present in a soil. Two methods were involved for the purpose of this research work. They are the sieve analysis and sedimentation analysis.

5. Analysis and Discussion of Results

The In Situ moisture content (w) is represented by the formula

$$w = \frac{\text{weight of wet sample}}{\text{weight of dry sample}} \times 100$$

$$\frac{ww}{ws} \times 100$$

The apparatus for moisture content determination for oven drying method are: weighing balance, an oven (In Situ temperature of 105-110^{o}C) and moisture cans. The procedure is weigh a representative sample of the soil in the natural or wet state (ww). Dry the sample to constant weight in an oven at a temperature of between 105-110^{o}C and leave it for 24hours. And then find the weight of the dry sample (ws).

The moisture content was then computed as

$$w = \frac{ww}{ws} \times 100$$

Test Results

Table 2: In Situ Moisture Content

Can No	**T10**	**N10**
Cant + wet sample, M_2 (g)	52.40	64.30
Can + Dry sample, M_3 (g)	48.40	58.70
Weight of empty Can, M_1 (g)	18.80	19.00
Weight of Wet Sample $M_2 – M_3$ (g)	4.00	5.60
Weight of Dry Sample $M_3 – M_1$ (g)	29.60	39.70
Moisture content w (%) $\frac{M_2 - M_3}{M_3 - M_1} \times 100$	13.51	14.11
Average Moisture Content (g)	13.81	

Laboratory Analysis of Field Samples, 2011

Note: T10 and N10 are used to determine the cans used in oven.

M_1 = Mass of bottle only

M_2 = Mass of bottle +soil + water

M_3 = Mass of bottle + dry soil

5.1 Atterberg Limits or Consistency Limits

This is the physical state in which soil exists. The consistency limit of any soil is the liquid limit, plastic limit and shrinkage limit. The liquid limit is the water content at which the soil changes from the liquid state to the plastic state. While the plastic limit is the water content below which the soil stops behaving as a plastic material. A plastic soil is the type of soil that can be molded into various shapes when it is wet. Plasticity is an important index property of fine-grained soils especially clayey soil. And the shrinkage limit is the smallest water content at which the soil is saturated. The linear shrinkage is determined for the purpose of this research work. This is because it relates more directly to other soil properties than the shrinkage limit. Linear shrinkage is defined as the change in length divided by the initial length when the water content is reduced to the shrinkage limit. It is expressed as

$$Ls = \frac{\text{Initial length – final length}}{\text{Initial length}} \times 100$$

Table 2: Atterberg Limits

A: Liquid Limit

Test	1	2	3	4	5
No of Blows	41	28	24	19	13
Can No	N5	N100	N20	N25	N30
Cant + wet sample, M_2 (g)	37.30	33.90	30.60	35.1o	33.10
Can + Dry sample, M_3 (g)	31.40	28.50	25.80	29.30	27.70
Weight of empty Can, M_1 (g)	13.80	13.70	12.90	13.60	14.30
Weight of Wet Sample $M_2 - M_1$ (g)	5.90	5.40	4.80	5.80	5.40
Weight of Dry Sample $M_3 - M_1$ (g)	17.60	14.80	12.90	15.70	13.4
Moisture content w (%) $\frac{M_2 - M_3}{M_3 - M_1}$ x	33.52	36.49	37.21	36.94	40.30

B: Plastic Limit

Test	1	2	3
Can No	V5	V6	V7
Cant + wet sample, M_2 (g)	20.10	17.10	17.40
Can + Dry sample, M_3 (g)	18.70	16.00	16.40
Weight of empty Can, M_1 (g)	9.60	9.90	9.90
Weight of Wet Can $M_2 - M_1$ (g)	1.40	1.00	1.00
Weight of Dry Sample $M_3 - M_1$ (g)	9.10	6.10	6.50
Moisture content W (%) $\frac{M_2 - M_3}{M_3 - M_1}$ x 100	15.38	18.03	15.38

Laboratory Analysis of Field Sample, 2011.

Linear shrinkage (Ls)
Original length of shrinkage mould (Lo) = 140mm
Final length of sample after oven drying (Lf) = 130mm

$$Ls = \frac{L - Lf}{Lo} \times 100$$

$$= \frac{140 - 130}{140} \times 100 \quad \frac{10}{140} \times 100$$

$$Ls = 7.14$$

5.2 Particle Size Analysis

This is used to determine quantitatively the proportions by mass of various sizes of particles present in a soil sample.

Table 4: Sieve Analysis

Sieve Sizes (mm)	Mass Retained, m1 (g)	% Retained, $\frac{M1}{M_0}$ x 100	% Passing
3.35	-	0	100
2.36	0.1	0.05	100-005 = 99.95
2.0	0.3	0.15	99.95-0.15 = 99.80
1.18	6.5	3.25	99.98-3.25 = 96.55
0.600	33.8	16.90	95.55-16.90 = 79.65
0.425	36.0	18.00	78.65-18.00 = 61.65
0.300	19.8	9.90	60.65-9.90 = 51.75
0.212	15.2	7.60	50.75-7.60 = 44.14
0.15	11.4	5.70	43.15-5.70 = 38.45
0.75	11.1	5.55	37.15-5.55 = 32.9

Initial Mass of Sample (m_0) = 200g. (Known value)
Laboratory Analysis of Field Soil Sample, 2011.

Table 5: Sedimentation Test

Total time in minutes	**Hydrometer Reading**	**Temperature(0^c)**	**Factors from Tables**		**Effective depth (cm)**	**Corrected hydrometer reading**	**Particle sizes (mm)**	**% of particle passing**	
								Fines	Whole
0.00	6.5	29.5	2.20	0.01245	19.30	8.70	0	75.69	48.55
0.08	6.5	29.5	2.20	0.01245	19.30	8.70	0.1934	75.69	48.55
0.17	6.4	29.5	2.20	0.01245	19.31	8.60	0.1327	73.96	47.44
0.25	6.3	29.5	2.20	0.01245	19.32	8.50	0.1094	72.25	46.34
0.50	6.2	29.5	2.20	0.01245	19.33	8.49	0.1774	70.56	45.26
1.00	6.0	29.5	2.20	0.01245	19.35	8.20	0.0548	67.24	43.13
5.60	5.6	29.5	2.20	0.01245	19.50	7.80	0.0367	60.84	39.02
4.00	5.3	28.0	1.77	0.0127	19.70	7.07	0.0282	49.98	32.06
9.00	5.0	29.0	2.07	0.0125	19.90	7.07	0.0186	49.98	32.06
16.00	4.5	29.0	2.07	0.0125	20.98	6.57	0.0140	43.16	27.68
2.500	4.0	29.0	2.07	0.0125	20.00	6.07	0.0112	36.84	23.63
60.00	3.5	29.5	2.20	0.01245	20.35	5.70	0.0073	32.49	20.84
120.00	3.2	30.5	2.35	0.0123	20.40	5.55	0.0051	30.80	19.76
240.00	2.7	31.0	2.64	0.01225	20.50	5.34	0.0036	28.52	18.29
480.00	2.5	30.0	2.34	0.01235	20.55	4.84	0.0026	23.43	15.03
1440.00	2.3	28.0	1.77	0.0127	20.75	4.07	0.0015	16.56	10.62

Laboratory Analysis of Field Soil Sample, 2011

Table 6: Soil Particle Size Analysis (mm)

Clay	**Silt**			**Sand**			**Gravel**			
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles

.002 .006 .02 .06 .2 .6 2 6 20 60 200

Field Survey, 2011

< 0.002 = clay
0.002 – 0.02 = silt
0.02 – 2.00 = sand
2.00 – 60.00 = gravel

The particle size analysis for this soil sample can be classified as silty gravel sand type of soil which makes it susceptible to continuous soil erosion hence the gullies get deeper with ease any time there is runoff. Also the sub soils in gullies can as well be classified as Acid Clay Soils as revealed by the different analysis carried out. This was however determined with the British Standard Sieve Sizes.

6. Conclusion and Recommendations

The handling, controlling and monitoring of soils in Benin City must be geared towards achieving quality environment for man. This also will go a long way in protecting natural resources such as water, air and land that are degraded as a result of human activities on the earth surface. From this framework, it is possible to articulate a position on the management of landscape when the nature of soils in exposed gullies is determined. This will undoubtedly help man to know the best way to control soil menace brought about by flooding and soil erosion and the eventual creation of gullies in Benin City. It is on this basis that moisture content of soils in gullies, atterberg limits and particle size analysis of soils are carried out so as to be able to proffer solution to the problems of gully erosion. The in situ moisture content shows an average of 13.81 percent which is an indication that the subsoil is always wet. The linear shrinkage (Ls) determined was 7.14. This is the smallest water content at which the soil can get saturated.

On the basis of the preceding, the following recommendations are made: Simply because of the nature of soils in Benin City, gullies should not be allowed to get to a worst state before solutions are sort for by individuals, corporate organizations and government who are always involve in the control of soil erosion. If not controlled mechanically but at least manual brakes should be used at the early stage of the development of gullies by those concern. Also, land use types should be well regulated by the government of the day. Places that are supposed to be for drains must not be built upon by anyone no matter how highly placed in the society. Landscape should be well structured by the government on the best land use type that will be suitable for it. Also, individuals and corporate organizations should join hands with government in avoiding exposing the sub soils which are highly susceptible to soil erosion and the need for all stakeholders to always plant grasses and trees in and outside their surroundings.

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