Int.J.Curr.Res.Aca.Rev.2018; 6(7): 87-92

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 6 Number 7 (July-2018)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2018.607.010

Geotechnical Characterization of Gully Erosion Impacted Soils in Owerri, IMO State Nigeria

P.N. Okeke* and C.S. Charles

Department of Environmental Technology, Federal University of Technology, Owerri, Imo State, Nigeria

**Corresponding author*

Abstract

Geotechnical characterization of gully erosion affected soils in Owerri, Imo State, Nigeria was carried out. Soil samples were collected from two locations impacted by gully erosion at varying depths of 0-15cm, 15-30cm and >30cm using soil auger. The same depths were maintained in sampling the non-gully impacted area (control). Geotechnical properties such as permeability, bulk and dry densities, Atterberg limits, compaction, shear strength and grain size were determined using standard procedures prescribed by ASTM D3418-05. The results showed that all the samples were non-plastic. Permeability values ranged from 4.0×10^{-2} to 3.8×10^{-3}cm/s in the gully affected areas, and from 2.5×10^{-2} to 1.0×10^{-3}cm/s in the control location. Similarly, the bulk density of the eroded areas was from 1.76 to 1.81g/cm^3 while the control were from 1.48 to 1.62g/cm^3. The shear strength at a constant maximum normal stress of 177.8KN/m^2 varied from 78.5 to 86.9 KN/m^2 at the gullied areas, while the control values were from 87.9 to 89.9 KN/m^2. The values of all the parameters increased with depth.

Article Info

Accepted: 04 June 2018
Available Online: 10 July 2018

Keywords

Geotechnical properties;
ASTM procedure;
Bulk densities;
Atterberg limit;
Shear strength;
Grain size;
Gully erosion;
Owerri Nigeria.

Introduction

Soil is one of the most valuable resources to humans. Some of its functions include food production, habitat for organisms, source of raw materials for construction works, and groundwater treatment. Unfortunately, the soil that has taken many years to form is being lost to erosion at an alarming rate.

According to Stirton (2016), half of the topsoil on the planet has been lost in the last 150 years. Apart from loss of fertile soils, eroded sediments often get deposited in lakes and rivers causing them to block and flood surrounding land (Mclaran, 1997). In Owerri, Nigeria soil erosion represents a major environmental hazard and the most serious ecological challenge confronting the communities. This has been attributed to high population density and over farming which degrade the soil and cause much of the native vegetation to disappear, leading to the development of gully erosion in Owerri (Imo State Government, 2010).

Past studies on soil erosion in Southeast Nigeria (Ofomata, 1988; Obiefuna and Onwueme, 1992; Ogbonna, 2012; Okodili, 2015 etc.) emphasized less on the contributions of geotechnical properties of the soil to gully formation. There is a need therefore to investigate and also incorporate the roles of these natural factors in any sound management and control of gully erosion in Owerri.

Materials and Methods

The Study Area

The area of study is in Owerri, Imo State Nigeria. It is located between latitudes $5^{0}23^{1}$ and $5^{0}34^{1}$ west and between longitudes $6^{0}50^{1}$ and 7^{0}E (Fig. 1).

The study area is characterized by a mean maximum temperature of 27^{0} C and a total annual rainfall exceeding 2000mm (Ezeonye and Emeribe, 2012).

It lies in the tropical rainforest or equatorial monsoon zone. The soil class is ferrealitic which is predominately porous, deep and lightly leached. The geology is Benin formation. Land use activities include farming, sand mining, settlements and industries.

Soil sampling

Soils were sampled from erosion affected and control area using soil augur and core sampler. At each location, samples were collected from three depths; 0-15cm, 15-30cm and >30cm.

The samples were prepared and standard procedure outlined by Head (1980) and ASTM-422 (2007) used in determining the following parameters: grain size, moisture content, dry density and bulk density. Others were hydraulic conductivity, Atterberg limit, shear strength and compaction test.

Results and Discussion

Tables 1 to 3 presents the results of the laboratory analysis of samples from erosion impacted and control areas.

From table 2, the mean percentage value for sand particles for locations A, B and C were 70%, 74% and 82% respectively. The average values for the fines were A (21%), B (17%) and C (18%). The values of sand decreased with depth while the fine particles had a reverse trend (Table 1).

The high percentage sand and low fines imply that little erosive force is needed to detach and transport the soil particles. Fine particles (silt and clay) help in aggregating soil particle and forming stable structure. Sandy soils are characterized by the predominance of macropores which encourage high water infiltration into the soil. But the removal of vegetation exposes the soil to direct impact of raindrops which rearrange the soil surface particles causing sealing, more runoff and erosion. This corroborates earlier findings by Poesen (1998) that the development of surface seals is very important with respect to the reduction of soil's infiltrability and the production of Hortonian overland flow. Surface seals also lead to decreased gaseous diffusion and seedling emergence (Technosynesis and Niger-Techno, 1999). This can delay re-vegetation process of the deforested areas.

Bulk density

The average bulk density values varied from 1.61 to 1.74 gcm^{-3} in the erosion affected area and 1.51 in control location. Generally, the bulk density values increased with depth. The high bulk density recorded in the erosion affected area can be attributed to the influence of human activities such farming, human and animal traffics which compact the soils. The implication of high bulk density is low water infiltration and high runoff that can cause erosion.

Permeability

The soil permeability is a measure indicating the capacity of the soil or rock to allow fluids to pass through it. (www.geotechdata.info/parameter/perm 2013). The permeability of the soil samples ranged from $2.25x10^{-2}$to $2.2x0^{-3}$ Cms^{-1} and from 4.10 x $10^{-2}$to 4.8 x 10^{-2} Cms^{-1} for locations A and B respectively (Tables 1 and 2).The control values varied from 0.5 x 10^{-2} to 2.56 x 10^{-2} Cms^{-1}. There was a general decrease of permeability with depth.

The relatively higher permeability of the topsoil can be attributed to the influence of sandy texture and high porosity of the medium, while the lower permeability of the subsoil is affected the argillic horizon. Similarly, the high permeability values of the control area over the gully impacted locations was probably due to the forest that adds organic matter, which results in a soil that is more open, porous and easily penetrated by water (Miller and Donahue, 1992). Low permeability of water in the soil decreases infiltration and increases runoff and soil erosion.

Compaction

Soil compaction is influenced by the moisture-density relationship. In the present study, the moisture-density relationship increases proportionally with the optimum moisture content (OMC). This agrees with Krishna (2015) findings that maximum dry density (MDD) increases proportionally with OMC in soil. He further states that compaction of soil at water content higher than the OMC results in a weak structured soil that is detrimental to the shear strength. When soil is compacted, porosity and infiltration are reduced, causing increased runoff, flooding and soil erosion.

Table.1 Values of parameters from location A

Location	Parameter		Depth		
			0-15cm	15-30cm	>30cm
A	Moisture content (1%)		11	12	13
	Dry density(g/cm^3)		1.61	1.60	1.59
	Bulk density (g/cm^3)		1.78	1.79	1.80
	Permeability (g/cm^3)		2.25x10^{-2}	1.96x10^{-3}	2.2x10^{-3}
	Particle size (%)	Gravel	0	0	0
		Sand	80	77	79
		Fines	20	23	21
	Atterberg Limit	Liquid Limit	N.P	N.P	N.P
		Plastic limit	N.P	N.P	N.P
	Shear strength	MNS (KN/M^2)	177.8	177.8	177.8
		SS (KN/M^2)	78.5	82.2	86.0
		θ	23^0	24^0	25^0
		C	3	3	4
	Compaction	MDD (mg^2)	1.80	1.84	1.89
		OMC (%)	8.0	8/6	9.2

Key: MNS = Maximum Normal Stress, SS = Shear Strength θ = angle of internal friction, C = Cohesion force, OMC = Optimum Moisture Content, MDD = Maximum Dry Density, NP = Non Plastic.

Table.2 Values of parameters from location B

Location	Parameter		Depth		
			0-15cm	15-30cm	>30cm
B	Moisture content (5)		7	9	9
	Dry density (g/cm^3)		1.63	1.64	1.66
	Bulk density (g/cm^3)		1.76	1.89	1.81
	Permeability (cm/s)		4.0 x 10^{-2}	4.4x10^{-2}	4.8 x 10^{-2}
	Particle size (%)	Gravel	11	8	9
		Sand	72	76	73
		Fines	17	16	18
	Atterberg Limit	Liquid Limit	N.P	N.P	N.P
		Plastic limit	N.P	N.P	N.P
	Shear strength	MNS (KN/M^2)	177.8	177.8	177.8
		SS (KN/M^2)	81.2	83.2	86.9
		θ	24	24	25
		C	2	4	4
	Compaction	MDD (mg^2)	1.86	1.90	1.93
		OMC (%)	7.2	8.2	9

Key: MNS = Maximum Normal Stress, SS = Shear Strength θ = angle of internal friction, C = Cohesion force, OMC = Optimum Moisture Content, MDD = Maximum Dry Density, NP = Non Plastic.

Table.3 Values of parameters from location C

Location	Parameter		Depth		
			0-15cm	15-30cm	>30cm
C	Moisture content (%)		7	9	11
	Dry density (g/cm^3)		1.68	1.66	1.65
	Bulk density (g/cm^3)		1.80	182	1.84
	Permeability (cm/s)		0.25x10^{-2}	2.56x 10^{-2}	1.0 x 10^{-2}
	Particle size (%)	Gravel	0	0	0
		Sand	87	82	78
		Fines	13	18	22
	Atterberg Limit	Liquid Limit	N.P	N.P	N.P
		Plastic limit	N.P	N.P	N.P
	Shear strength	MNS (KN/M^2)	177.8	177.8	177.8
		SS (KN/M^2)	87.9	88.9	89.9
		θ	25	25	25
		C	5	6	7
	Compaction	MDD (mg^2)	1.87	1.92	1.98
		OMC (%)	8.8	9.2	10.0

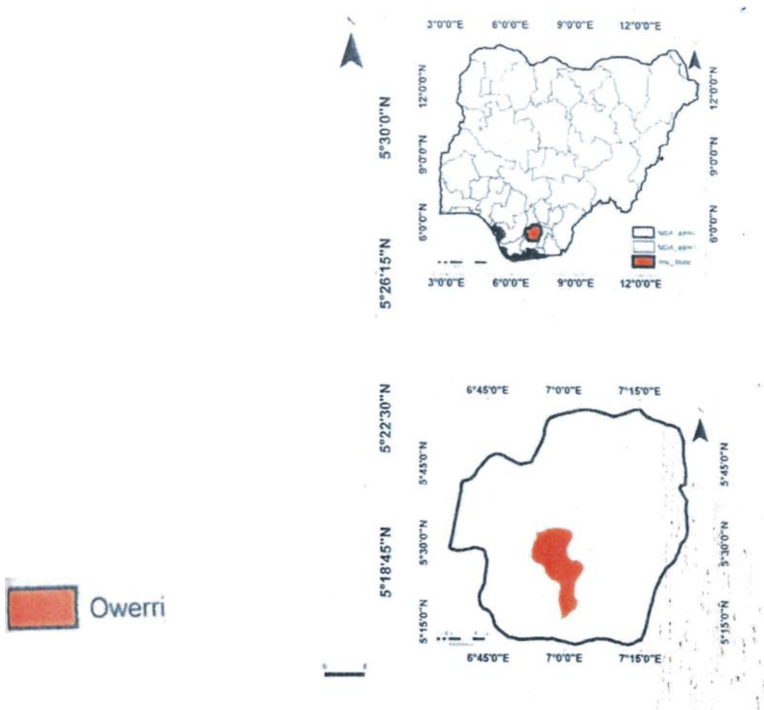
Key: MNS = Maximum Normal Street, SS = Shear Strength θ = angle of internal friction, C = Cohesion force, OMC = Optimum Moisture Content, MDD = Maximum Dry Density, NP = Non Plastic.

Table.4 Means and standard deviations of the geotechnical properties of the gully affected and control sites

	LOCATION		
PARAMETERS	A (Impacted Area)	B (Impacted Area)	C (Control)
Moisture content%	12.000± 1.0000	8.3333± 1.1547	9
Dry Density (g/cm^3)	1.60000± 0.0100	1.6433± 0.0153	1.5033
Bulk Density (g/cm^3)	1.79± 0.100	1.7833± 0.02517	1.67
Permeability (cm/s)	0.00889± 0.0118	0.044± 0.004	0.0172
Gravel %	0± 0.0000	9.3333± 1.5275	0.0000
Sand %	78.6667±1.5275	73.6667±2.0817	82.3330
Fines %	21.3333± 1.5275	17.0000± 1.0000	17.6667
Liquid Limit	N.P	N.P	N.P
Plastic Limit	N.P	N.P	N.P
MNS (KN/M^2)	177.8± 3.48E-14	177.8± 3.48E-14	177.8000
SS (KN/M^2)	82.2333± 3.7501	83.7667± 2.8919	88.9000
MDD (mg^2)	1.8433±0.04509	1.8967± 0.0351	1.9233
OMC (%)	8.6±0.6000	8.1333± 0.0902	9.3333

Key: MNS = Maximum Normal Street, SS = Shear Strength θ = angle of internal friction, C = Cohesion force, OMC = Optimum Moisture Content, MDD = Maximum Dry Density, NP = Non Plastic.

Fig.1 Map of the study area



Shear strength

At a maximum normal stress of 177.8KN/m^2 (Table 1), sample from location A (0-15cm) had a shear strength of 78.5KN/m^2 and a cohesion force of 3KN/m^2. The subsoil (15-30cm) sample had a shear strength of 82.2KN/m2 and cohesion force of 3KN/M^2 while at a greater depth of the subsoil (>30cm), the shear strength was 86.9KN/M^2 and cohesion force of 4KN/M. Similarly, location B recorded shear strength of 81.2, 83.2 and 86.9KN/M^2 for depths of 0-15cm, 15-30cm and >30cm, respectively under constant MNS (177.8KN/M^2). The control location (Table 3) showed higher shear strength values than the impacted locations A and B.

Results from all the locations indicate that the shear strength generally increased with depth, and this could be attributed to higher percentage of clay in the subsoil (Argillic horizon). Clay is a binding agent and contributes to the cohensive force that increases shear strength. The lower shear strength values of the eroded areas when compared with control was an indication that the impacted areas had less cohesive force and therefore easily eroded. According to Dumbleton (2007), increase in shear strength is as a result of increase in cohesive force. The impacted locations had lower cohesive force values probably due to land use activities which has removed the vegetation; the source of organic input to the soil. Organic matter contributes in soil aggregation that helps in reducing soil erodibility.

Atterberg limit

In determining Atterberg Limit, it is necessary that the soil sample forms a I/8" (3.22mm) diameter from which the moisture content is taken prior to the crumbling. In this study, the required diameter could not be formed and there was no way to determine the moisture content at the transition point. Hence the soil is undefined.

According to ASM D3418-05, if after several attempts of successively higher water content, and the soil continues to slide in the cup or if the number of blows required to close the groove is always less than 25, the soil is recorded as non-plastic without performing the plastic limit test. The soils in this category did not have plastic limits and liquid limit values (www.eng-lips.com). Generally, soils with low binding force of cohesion can easily be detached and transported resulting to increase in depth of already formed gully or development of new ones.

This study reveals the influence of selected geotechnical properties such as compaction, shear strength, Atterberg's limit, bulk density, permeability etc on gully formation and development in Owerri, Imo State, Nigeria. Soil compaction increased the bulk density, reduced porosity and water infiltration. Similarly, low permeability in the argillic horizon hindered water movement into the soil and encouraged over land flow. High percentage sand coupled with low fine content created poor structural stability that was partly germane to high susceptibility of the area to gully erosion.

References

Ezeonye, M.N., and Emeribe, C.N. 2012. Rainfall Erosivity in Southeastern Nigeria. DO1 http://dx.doi.org/10.4314/egesm vol. 512.1.

Head, K.H., 1980. Manual of Soil Laboratory Testing. Vol. 1 Soil Classification and Compaction Test. ELE Int. Ltd. London.

Imo State Government. 2010. Retrieved from Imo State – Wikipedia, the free encyclopedia en.wikipedia.org/wiki/Imo-State.

Krishna, R., 2015. Engineering Properties of Soil base on Laboratory Testing: ULC 158 Experiment. Retrieved from: www.kofers.com/files/exams-dbndituahby.

Maclaren, R.G., and Cameron, K.C 1997. Soil Science: Sustainable. Oxford University Press, New York.

Miller, R.W., and Donahue, R.L. 1992. Soils. An Introduction to soils and Plant Growth. Prentice – Hall of India, New Delhi.

Obiefuna, J.C., and Onwueme, I.C. 1992. Agroforestry Management Systems for Erosion Control on Reclaimed Gulleys of S.E. Nigeria. In S.E. Nigeria. 20-25 September, 1992.

Ofomata, G.E.K., 1988. The Management of Soil Erosion in Southeastern Nigeria. Proceedings of the International Symposium on Erosion in S.E. Nigeria. Pp 3 – 12.

Ogbonna, J.U., 2012. Understanding Gully Erosion Vulnerability in Old Imo State using Geographical Information System and Geostatistics. American Journal of Geographic Information System. Bol. 1 No. 3, 2012, 66 -71.

Okodili, N., 2015. The Rage of Erosion in Imo, South-East Nigeria. Ihenationonlineng.net? Home>SouthEast.

Poesen, J., 1988. A review of the studies on the mechanisms of incipient Riling and Gullying in the Belgian Loam Region. Proceedings of the International Symposium on Erosion in S.E. Nigeria. Pp 13 – 20.

Stirton, B., 2016. Soil Erosion and Degradation/Threats/WWF. Retrieved from ww.worldlife.org/threats/soil.

Technosynesis and Niger-Techno Ltd 1999. Soil Erosion Control in Imo and Anambra States. Final Report, Vol. 1: Summary Report. Federal Ministry of Agriculture and Rural Development of Nigeria. Technosynesis S.p.a., Planning and Engineering Consultants, 148p.

www.eng-lips.com

www.geotechdata.infor/parameter/perm....(2013)

How to cite this article:

Okeke, P.N., and Charles, C.S. 2018. Geotechnical Characterization of Gully Erosion Impacted Soils in Owerri, IMO State Nigeria. *Int.J.Curr.Res.Aca.Rev.* 6(7), 87-92. **doi:** https://doi.org/10.20546/ijcrar.2018.607.010