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STABILIZATION OF EROSION CONTROL USING BERMUDA (*CYNODON DACTYLON*): A CASE STUDY OF GULLY EROSION SITE AT UMUALUM NEKEDE OWERRI IMO STATE NIGERIA.

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ABSTRACT

Gully erosion remains a major environmental problem in southeastern Nigeria, causing soil degradation, infrastructural damage, as well as loss of agricultural productivity. This study evaluated the effectiveness of Bermuda grass (Cynodon dactylon) in stabilizing a gully erosion site located along Old Nekede Road, Owerri West, Imo State, Nigeria. Soil samples were collected from eroded (bare) and non-eroded (Bermuda grass-covered) sections of the gully and subjected to laboratory analyses including grain size distribution, moisture content determination, Atterberg limits, and direct shear strength tests. Results showed that the non-eroded soils contained higher fine particle content (24.8%) compared with eroded soils (18.0%). Moisture content was significantly lower in the vegetated area (22.7%) compared to the eroded section (24.3%), while both soils were classified as non-plastic. Shear strength analysis indicated higher shear resistance in the vegetated soils (99.5 kN/m²) compared to eroded soils (87.9 kN/m²). The findings demonstrate that Bermuda grass improves soil stability by enhancing shear strength and surface protection against erosion processes. Therefore, vegetation-based stabilization using Bermuda grass is recommended as an effective and sustainable method for controlling gully erosion in the study area and similar environments.

KEYWORDS: Bermuda grass, soil stabilization, gully erosion, shear strength, erosion control.

1.0 INTRODUCTION

Soil is a vital resource for producing the food and fibre needed to support an increasing world population (Obineche et al., 2022; Pappendick and Parr,1992). They continued to state that soils are dynamic resource that supports plant life. It is made of different-sized mineral particles, organic matter, and numerous species of living organisms. Thus, the soil has biological, chemical, and physical properties, some of which are dynamic and can change in response to how the soil is managed. Soils are classified as natural bodies on the basis of their profile characteristics (Brady and Weil,1999). Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Changes in the capacity of the soil to function are reflected in soil properties that change in response to management or climate. Its production can be limited by the factors such as soil characteristics, agro-ecological factors, topography, parent material, land use, and management among others.

Most farmers in south-eastern Nigeria regard the soil to be the same in every aspect because they are all the same based on geographical location. Igwe (2003) posit that most soils in southeastern Nigeria are not classified but are utilized in land use activities leading to water erosion. Onweremadu (2007) stated that characterization and classification of soil of any given location help in generating soil-related data which are useful in proper and sustained use of soil resource. There is an increasing demand for information on soils as a means to produce food. Agriculture is the predominant economic activity in Nigeria and because of agricultural development and increasing demand for experimental data in Nigeria, much work is carried out on soil characterization. This provides the basic information necessary to create functional soil classification schemes and assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa,1998).

According to Oriako et al. (2022) soil erosion has been a challenging factor in the southeastern part of Nigeria where vast lands are being affected, causing transposition of topsoils, hence; causing the degrading of soil. Water and wind are found to be the major agents of soil erosion and land degradation; each contributes to a substantial extent of soil loss annually. The loss of topsoil from farmland could be reproduced in deficit crop production potential, lesser shallow water quality and spoiled drainage systems (Morgan, 1991). Agricultural production, sustenance and management aimed at food safety and sustenance have been greatly undermined in this section by the threat postured by soil destruction although the accessibility of agricultural farmlands for production and construction events has been significantly minimized by the losses initiated by the associated problems with soil erosion (Okorafor et al ., 2017). The erosion of soils is seen as a major ecological difficulty as it utterly threatens and destroys natural resources as well as the environment (Rahman et al., 2009). Soil erosion diminishes soil quality and reduces the productivity of natural, agricultural and forest ecosystems (Pimentel, 2006). Water and wind erosion are the two major constituents of land degradation: water and wind erosion cause 84% of the global magnitude of degraded land mass, excessive erosion, and most notable environmental defects (Mbagwu, 1996). Soil characterization is an essential part of the determination of the nature and extent of soils on a construction site or earth system in order to review subsurface conditions and ensure that the soil composition adhere to any lead down regulations. Depth characterization also provides a key parameter in determining volumes of contaminated soil. Recently El- Swaify (1994) observed that the third world countries suffer from soil degradation incurred due to the maladministration of land; this has posed a main distress that threatens pastoral growth and economy. According to Wang and Gong (1998) one of the major factors that enhance the global biosphere and agricultural development practice is the quality of soil. The aim of this research is to study the influence of Bermuda grass (Cynodon dactylon) on the stability of an erosion site, using one of the largest erosion sites in Old Road Nekede, Owerri-West Imo State Nigeria. This study is limited to investigating the influence and contributive impact of the application of Bermuda grass in erosion control and soil stabilization.

2.0 MATERIALS AND METHOD

Description of Study Area

The study was conducted at the gully located along the old Nekede road in Owerri West L.G.A of Imo State (Figure 1). It lies between longitude 5^0 25^1 03^{11} N and latitude 6^0 55^1 06^{11} E. The study area was about 3 km from Owerri main town (Obineche et al., 2020). It was characterized by a main annual rainfall ranging from 2000-2500 mm, a mean temperature ranging from 26-28 ^oC and humidity ranging from 70-80% (Obineche et al., 2021). Different samples were collected on the bare soil of the gully affected area (Erodible) and also on the Bermuda grassed area (No-erodible). The tools utilized in the sample collections include; soil anger, labeled containers and measuring tape.

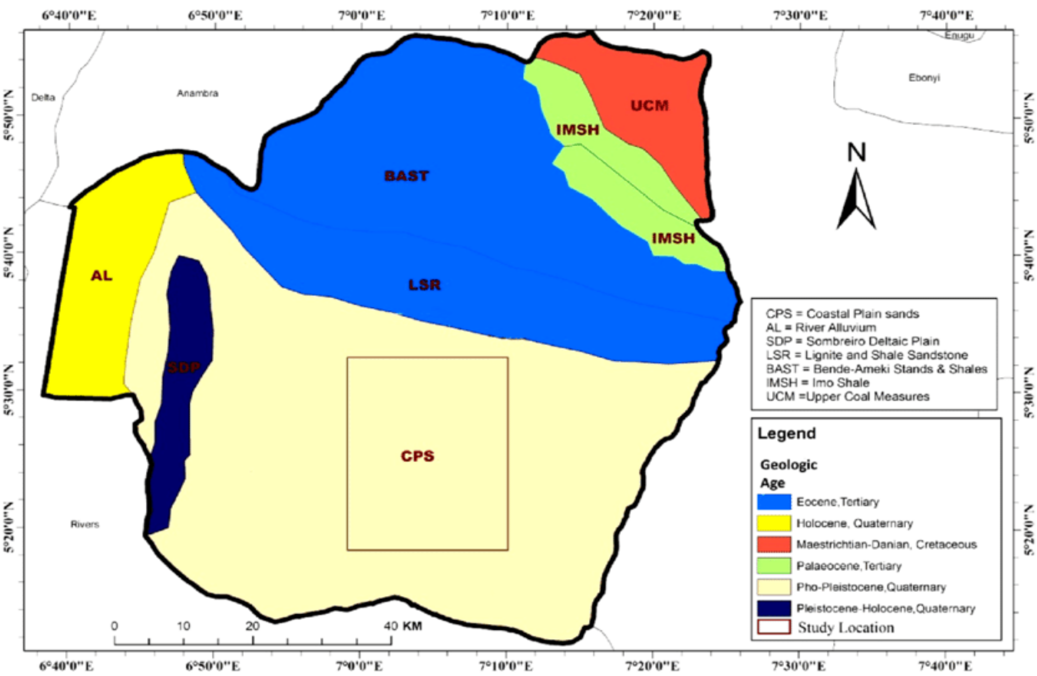

Figure 1: Map showing geologic structure of the study area.

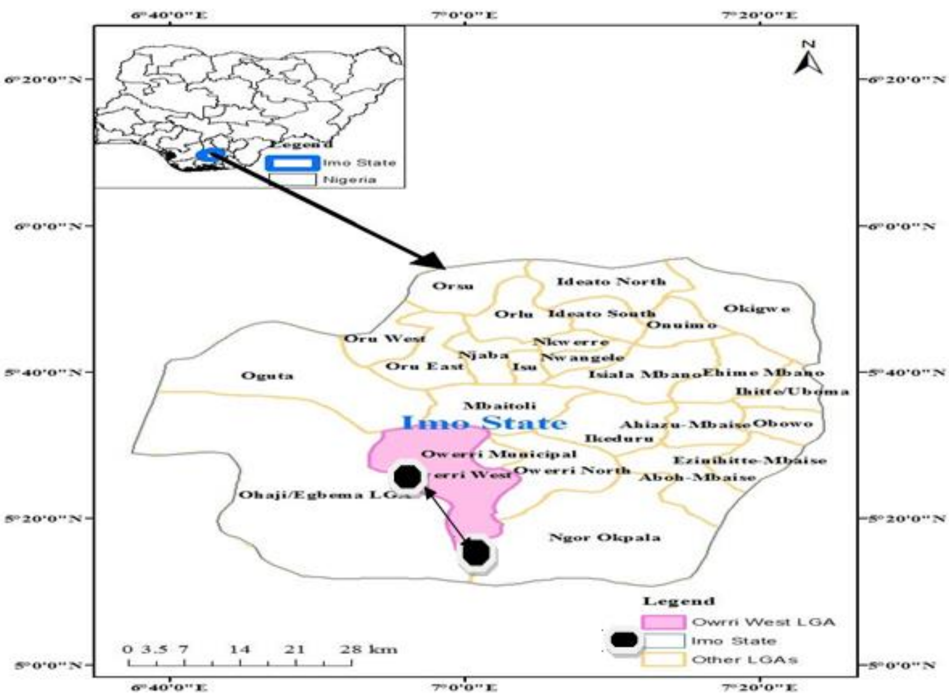

Figure 2: Map showing the experimental location.

Soil Sampling

Soil samples were collected from two different locations within the study area: Eroded soil samples: obtained from the bare gully surface.

Non-eroded soil samples: obtained from areas stabilized with Bermuda grass (Cynodon dactylon).

Sampling was carried out using a soil auger, labeled sample containers, and measuring tape to ensure accurate identification and depth consistency. The collected samples were transported to the laboratory for analysis.

Laboratory Analysis

Laboratory tests were conducted to determine the physical and engineering properties of the soil samples. The tests performed included grain size distribution, moisture content determination, Atterberg limits, and direct shear strength tests.

Grain Size Distribution Test

The grain size analysis was conducted using the sieve analysis method. Approximately 150 g of soil sample was washed through a 2 mm sieve to remove fines and then oven-dried at 105–110 °C for 24 hours. The dried samples were passed through a series of standard sieves, and the mass retained on each sieve was recorded to determine the percentage passing and particle size distribution.

Moisture Content Determination

The natural moisture content of each soil sample was determined using the oven-drying method. The samples were weighed in airtight containers, dried in an oven at 105–110 °C until constant weight was achieved, and reweighed. Moisture content was calculated as the ratio of the weight of water lost to the weight of dry soil, expressed as a percentage.

$$M.C - \frac{W1-W2}{W2-WC} \; X\,100 \qquad 1$$

Where,

MC = moisture content

W1=weight of container +wet soil

W2 = weight of container + oven dry soil

Wc= weight of empty container

Atterberg Limits Test

Liquid and plastic limit tests were conducted to determine the consistency characteristics of the soil. For the liquid limit test, soil paste passing the 425 µm sieve was placed in the liquid limit device and subjected to repeat blows until the groove closed at approximately 25 blows. The plastic limit was determined by rolling soil threads until they crumbled at a standard diameter. The results were used to classify soil plasticity.

Direct Shear Strength Test

The shear strength parameters of the soil were determined using the direct shear box apparatus. Undisturbed soil samples were trimmed to fit the shear box, and normal loads were applied vertically. Horizontal shear force was gradually applied until failure occurred. The resulting data were used to compute cohesion (c), angle of internal friction (φ), and shear strength for both eroded and non-eroded soil samples.

3.0 RESULTS AND DISCUSSION

Grain size analysis test

From the analysis of the eroded soil sample, the total amount of fine soil particles in percentage is 18.0%. It was determined that 98.0% passed through, the 2.0 mm sieve while the 17.2% passed through the 0.075 sieve. The analysis of the non-eroded soil sample yielded a 24.8% of fine soil particles. It was determined that 98.2% of fines passed through the 2.0mm sieve while 25.5% passed through the 0.075mm sieve.

Sample: Eroded Soil Sample of Bare Gully Soil

Weight of sample before washing and drying = 60g weight of sample after washing and drying= 49.2g therefore, mass lost of washing (mass of fines) = 10.2g percentage (%) of fines = 18.0% dry of residue, mass = 49.2g

Table 1: Grain size analysis test for eroded soil sample.

SIEVE SIZE (mm)	MASS RETAINED (g)	MASS PASSING (g)	PERCENTAGE PASSING (%)
2.000	1.2	58.8	98.0
1.180	3.8	55.0	91.7
0.850	4.3	50.7	84.5
0.600	6.3	44.4	74.0
0.425	10.2	34.2	57.0
0.300	11.2	22.7	37.8
0.150	6.1	16.6	27.7
0.075	5.3	10.3	17.2
PAN	**0.4**	**9.9**	**0**

Table 2: Grain size analysis test for non-eroded soil sample.

Sieve size (mm)	Mass retained (g)	Mass passing (g)	Percentage passing (%)
2.000	1.1	58.9	**98.2**
1.180	4.1	54.8	**91.3**
0.850	3.9	50.9	**84.8**
0.600	6.5	44.4	**74.0**
0.425	9.1	35.3	**58.8**

0.300	10.2	25.1	**41.8**
0.150	5.1	20.0	**33.3**
0.075	4.7	15.3	**25.5**
PAN	**0.4**	**14.9**	**-**

Physical properties of the soil

The result of the moisture content shows soil extracted for the eroding land area to be 243%, while that from the non-eroding land was determined to be 22.7%. The varying values of the two samples are mainly due to the difference in texture and permeability of the soils. While the result of the bulk density indicates that eroded soil has 16.9%, and non-eroded has 17.4 % showing slight variation. The eroded soil sample contained almost no traces of clay content hence the liquid and plastic limits is limited non-plastic, the Waterberg test for the non-eroding soil of the Bermuda grassroots also has no trace of clay content, hence the liquid and plastic limits is termed non-plastic.

Shear Strength Test

The shear strength parameters were determined by using the direct shear test method. The eroded sample has 5kn/m^2 as the value of cohesions and an angle of internal friction of 25^o, the shear strength was obtained as 87.9kn/m^2. The non-eroded soil sample has a cohesion value of 5 km/m^2 and an angle of internal friction 25^o. The shear strength was obtained was 99.5 kn/m^2. The results shows that the eroded soil has a lower value for shear strength, this means tht it can only carry a weight of 87.9 kn/m^2 of soil while the non-eroded soil is capable of carrying 99.5kn of load per unit area of soil in m^2.

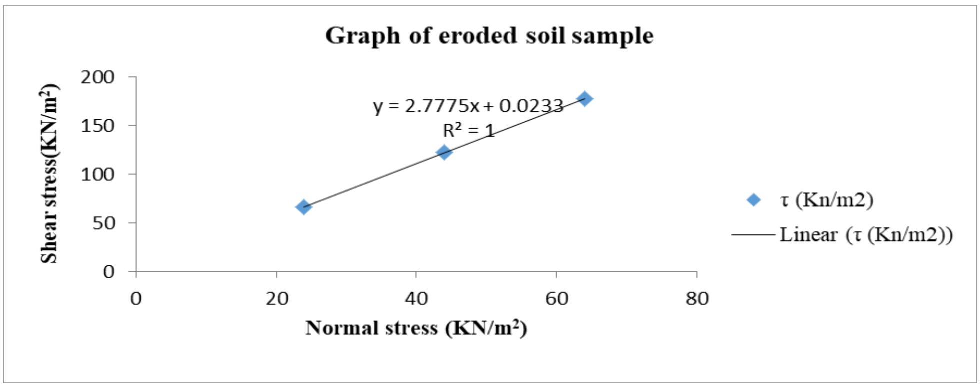

Figure 3: Graph of normal stress component for both samples.

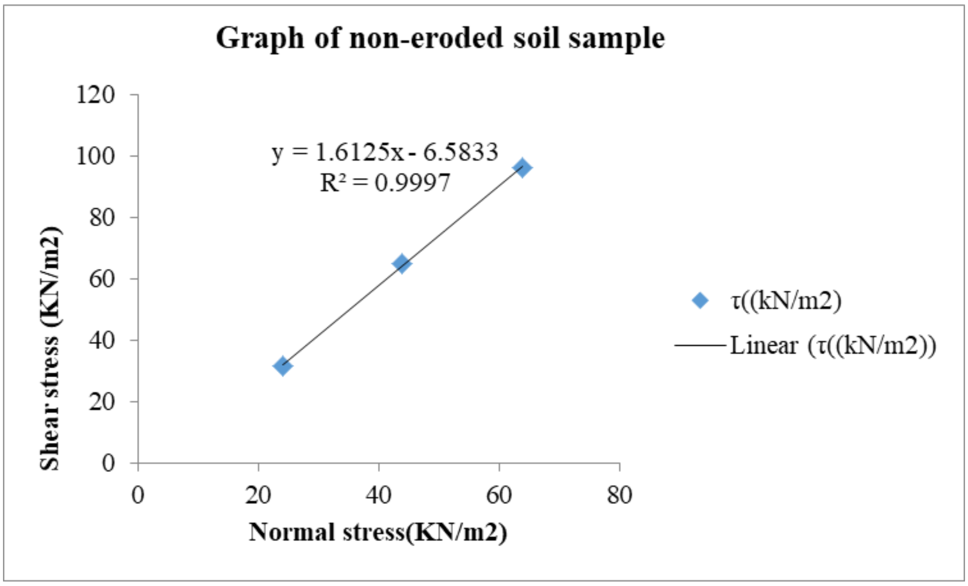

Figure 4: graph of Shear stress component for eroded soil sample.

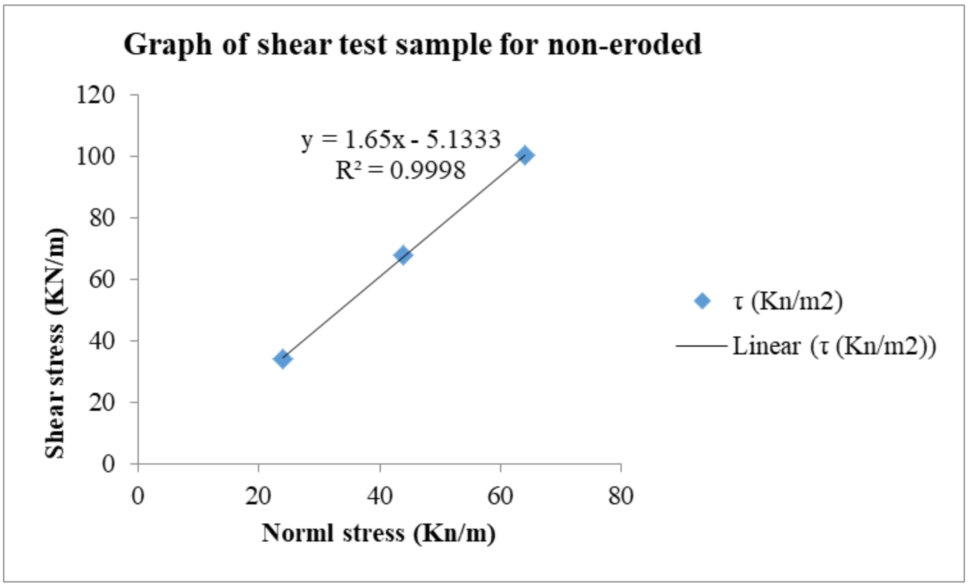

Figure 5: Shear strength component for non-eroded soil sample.

Table 3: computation of shear strength

Sample	C(kN/m^2)	ϕ(º)	ση(KN/m^2)	τ((kN/m^2)
Eroded	5	25	177.8	86.0
Non- eroded	5	28	117.8	96.8

Where, C= cohesion (KN/m^2)

Φ= angle of internal friction (º)

ση= maximum normal stress τ((kN/m^2)

τ= shear strength ((kN/m^2)

DISCUSSION

The results of this study demonstrate the significant role of vegetation in improving soil stability at erosion-prone sites. The grain-size distribution analysis revealed that soils under Bermuda grass cover contained a higher proportion of fine particles (24.8%) compared with the eroded bare soils (18.0%). This indicates that vegetation reduces the detachment and transport of finer particles through canopy interception of rainfall and reduction of runoff velocity, thereby minimizing erosion processes (Morgan, 1991; Pimentel, 2006). The fibrous root system of Bermuda grass also helps bind soil particles together, enhancing aggregate stability and reducing susceptibility to erosion.

Moisture content results showed slightly lower moisture content in the vegetated soil (22.7%) compared with the eroded soil (24.3%). Improved infiltration and evapotranspiration associated with vegetated surfaces likely contributed to this difference. Vegetation enhances soil porosity through root penetration, which promotes water movement into the soil profile and reduces surface runoff responsible for gully expansion (Rahman et al., 2009). Although both soils were classified as non-plastic, differences in moisture dynamics and soil structure contributed to variations in mechanical performance.

Shear strength analysis provided clear evidence of the stabilizing effect of Bermuda grass. The vegetated soil exhibited higher shear strength (approximately 99.5 kN/m^2) compared with the eroded soil (about 87.9 kN/m^2). Increased shear resistance indicates improved load-bearing capacity and reduced likelihood of slope failure. Vegetation roots act as reinforcing elements that increase soil cohesion and resistance to shear deformation, thereby improving slope stability and erosion resistance (Mbagwu, 1996; Oriako et al., 2022).

Overall, the combined improvements in fine-particle retention, moisture regulation, and shear strength confirm that Bermuda grass significantly enhances soil structural stability and reduces erosion susceptibility in gully-affected environments.

4.0 CONCLUSION

The study evaluated the effectiveness of Bermuda grass (Cynodon dactylon) in stabilizing a gully erosion site at Old Nekede Road, Owerri West, Imo State. Laboratory analyses showed that soils under Bermuda grass cover exhibited higher fine particle retention, improved moisture regulation, and greater shear strength compared with bare eroded soils. These improvements indicate that the fibrous root system of Bermuda grass enhances soil cohesion and structural stability, thereby reducing erosion susceptibility. Consequently, the adoption of vegetation-based stabilization techniques, particularly the use of Bermuda grass, is recommended as a sustainable and cost-effective solution for controlling gully erosion in the study area and other erosion-prone environments.

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