Journal of Earth Sciences and Geotechnical Engineering, vol. 3, no. 1, 2013, 27-39
ISSN: 1792-9040 (print), 1792-9660 (online)
Scienpress Ltd, 2013

Effect of Disturbed Soil Properties on Gully Growth/Soil Loss at Underground Drainage Construction Site, UYO

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Abstract

Physico-chemical and erodibility characteristics of soil under anthropogenic disturbance by mechanically land-grading along the underground (tunnel) drainage construction sites in Uyo, Nigeria were investigated using standard methods and correlated with gully growth and soil loss. Statistical and parameter analyses evaluated spatial variability, correlations and significant differences. The disturbed soil had predominantly coarse grain sands(86%), low fines (<10%), high bulk density, low total porosity and very low permeability, indicating compacted, homogenous texture from the crest to the tunnel bottom, but permeability showed significant variability ($CV \geq 40\%$). Soil chemical properties had low correlations with gully morphometric degradation and soil loss; however, physical properties, particularly low clay and silt content, total sand, and bulk density highly reduced gully geometric degradation and volume of soil loss. Large proportions of bases (Ca^{++} and Mg^{++}) sufficiently reduced SAR, hence reduced soil erodibility at base sites. Silt and clay correlated highly with width and depth increments, and volume loss (r = 0.70–0.78) down the slope but longitudinal degradation was the resultant effect of runoff on the steep side-slope. Clay, silt, total sand and bulk density moderately reduced width and depth erodibility, correlating with 60% of volume loss.

Keywords: disturbed soil, mechanical land-grading, gully erosion, tunnel drainage site, soil properties, soil loss.

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1 Introduction

Land use in Uyo vegetated peri-urban sub-watershed is affected by rapid urban expansion and renewal leading to encroachment of adjacent rural areas for removal of soil for projects in the municipality. Land use for sand- mining has heightened in many sub-urban areas of the state capital [1]. Land grading for drainage work especially in Uyo, with a flat topography, has considerably increased impervious surface to infiltration, resulting in epochal increase in urban flood occurrences as a mark of anthropogenic disturbances. Recently, actions to curb the urban flood scenario have been undertaken. One of such actions is the grading of Itam road axis in Uyo peri-urban to construct an underground tunnel drainage channel to an outfall at the existing dissected ravine, a natural grass waterway for flow to the upstream section of Ikpa river. However, the reclamation work initiated soil erosion along the channel banks, aided by the land grading marks, the denuded soil surface, the imposed bank slope and the delay in completion of work under the high tropical rainfall in the area [2]. A recent study of the effect of rainfall on gully growth at the project area showed that a maximum of only 30%-40% of soil loss in the gully morphometric degradation was explained by rainfall amount [2]. The depth of the degraded gully geometry increased marginally with duration (weeks) of rainfall, perhaps, because the cut soil has exposed impervious sub-layer during the earlier land grading process, which limited extensive vertical or depth infiltration by rainfall. The grading of sub-surface affects the resistance of soil to erosion which is offered by the mechanical and chemical properties of the soil. It also decreases the large particle sizes offered by sands in the topsoil which has now been degraded [3]. The degradation of soil by mechanical land-grading affects soil quality by deterioration of its physical, chemical, biological and textural properties[3]. Therefore, apart from rainfall, soil properties deterioration could be a major contributor to gully growth [4]. Soils differ in their susceptibility to erosion (erodibility) depending on natural (properties) and human factors. For instance, increase in soil erodibility is inversely proportional to aggregate stability reduction; while clay and organic matter contribute to improve aggregate stabilities,large sand grains reduce soil erodibility; hence soil texture and structure do affect erodibility [5]. Therefore, the objectives of this research were to investigate the site properties of the disturbed soil at an underground tunnel drainage work site, Uyo and their characteristic relationships to erodibility, gully growth and soil loss under the impinging rainfall/runoff conditions.

2 Materials and Methods

2.1 The Study Area

Uyo Local Government Area lies between Latitudes 4^0 30^1 and 5^0 32^0 North and Longitudes 7^0 30^1 and 7^0 36^0 East, within the tropical rainforest belt with evergreen vegetation. It is the capital city of Akwa Ibom State and presently occupies a total land mass of 1,250,000km^2 of which a substantial percentage is used for agriculture. About 50,000 ha of its area are affected by gully erosion, with gully sites and ravine wide spread over the area [6]. The geological formation in Uyo is the Coastal Plain Sands, which occupies more than 75% of Akwa Ibom State soils [7]. The soils are derived from the parent materials and are highly weathered and dominated by low activity clays; the dominant soils in Akwa Ibom State are of inter—fluvial slope with a pattern of increase in clay content down the profile and are generally of low organic matter content (OMC), low water storage capacity, low CEC and highly susceptible to erosion [7,8]. The dominant forest types in Akwa Ibom State include the saline water swamp, fresh water swamp forest and the rainforest. The native vegetation has been completely replaced by secondary forest of predominantly oil palms, woody shrubs such as grasses. The forest is noticeable around hamlets, watercourses, tree crop plantations and forest reserves.

The state lies North of the equator and within the humid tropics and has a mean annual temperature between 26-27^0 C and two distinct seasons: the wet season (April to October) and the dry season (November to March). In the south and central parts of the state, the rainy season lasts for about 7 or 8 months but, towards the far north of the state, it reduces to about 6 months. The rains are of high intensity and of bimodal pattern with two peaks in July and September, and a period of 2-3 weeks of little or no rain (called August Break) in between.

The dry season gives rise to the post-season characteristics of a maximum rainfall regime in which the months with the heaviest rainfall are usually June and July for the first rainfall maximum and September for the second maximum. The annual rainfall ranges from 2,000mm on the northern fringe to over 3,000mm along the coast.

2.2 Field Measurements

The area is a forested natural ravine good for drainage water waterway as it empties into Ikpa river which drains the capital territory and its suburbs. It has just been used for the underground drainage and part of the site was reclaimed but some gullies developed on the reclaimed soil and were growing. Ephemeral gully erosion is due to the action of running water or concentration of runoff and it begins with rill. Hence, the measurement was carried out during the onset period of rains in the region ((March and April) until the recession period (October) to examine the effect of soil properties under rainfall on gully growth and soil loss at the drainage construction site. Five (5) gullies were randomly selected at the land reclamation site along Itam ravine for the study.

The investigation was carried out in 2009 and 2010 at site-specific intervals; measuring gully dimensions (length, width and depth) from gully initiation to full development. Simultaneously, measurement of soil properties was done before and during the stages of gully erosion. Distribution of gullies was one at the crest, three at mid slope and two at the trench bottom. The initial and subsequent changes in length, width and depth of respective gullies and soil properties were measured at weekly intervals and used to determine the growth of the gullies. A 30m linen tape, locally constructed ranging poles and pegs were used in measurement. The gully top width, depth and bed width were measured at gully mouth, gully head and at carefully selected points, usually at regularly spaced intervals of between 1m and 2m depending on the length of the gully. A tape was stretched out across its top width to determine its dimension. Gully depth was measured with another tape stretched from the surface to the gully bed with the aid of the ranging pole.

Determination of soil properties at each gully site soil properties was determined from soil samples at the site along the slope before and during gully progress from initiation to maturity. Some physical and chemical properties were determined as in [9] and [10].

For Saturated hydraulic conductivity**,** a 75mm (ID) soil augur was used to cut the soil core sample, which was placed on a basin of water and allowed to saturate through capillary rise. The saturated core was placed in a funnel, suspended on tripod stand with a cylinder placed under the funnel to collect the discharged fluid. An empty core cylinder with a known constant head was placed on top of it and secured with a masking tape. The water level was constantly maintained throughout the experiment, and water passing through the soil column was collected through the funnel into a measuring cylinder. Saturated hydraulic conductivity was calculated as [11]:

$$K_{sat} = QL / \Delta h.a.t \tag{1}$$

where: K_{sat} is saturated hydraulic conductivity (cm/hr), Q is discharge rate (cm^3/hr), L is length of soil column (cm), Δh is change in hydraulic head (cm), L is also Length of cylinder (cm), h is Length of cylinder with opening (cm), a is cross-sectional area (cm^2), t is time of percolation (min).

For bulk density, **t**he core samples were oven-dried at a temperature of 105^0C to a constant weight. The bulk density was calculated using the mass-volume relationship as

$$Bd = M_s / V_t \tag{2}$$

where Bd is bulk density (g/cm^3), M_s is mass of dry soil (g), V_t is total volume of soil (cm^3). The total volume of the soil was calculated from the internal dimensions of the cylinders. Total porosity was calculated from particle density and bulk density using the formula as described by [12], [13]:

$$f = 1 - \frac{(1-Bd)}{ls} \tag{3}$$

where f is total porosity (m^3/m^3), Bd is bulk density (kg/m^3) and ℓs is particle density. The particle size distribution was determined using the Bouyoucos Hydrometer method [9] [10] after dispersing the soil particle with sodium hexametaphosphate solution (SHMP, 50g/L). The textural class of the soil was determined using textural triangle. For soil structure, the exposed soil face on the gully side was carefully studied with the aid of the hand lens. The arrangement of soil aggregate was described as either very fine granular, fine granular, coarse granular or blocky (platy or massive) following Ahn (1971)'s specifications [14], [15].Furthermore, the identified structures were coded as (1), (2), (3) and (4) respectively and used in determining soil erodibility k-factor by assigning absolute values in the order: 1, 2, 3 and 4, according to [15].

Erodibility k-value was estimated from soil properties. Soil erodibility is the susceptibility of soil to erosion and is affected by inherent soil properties. Values of k can be calculated from equations 4 and 5 [16], [17]. Where silt + very fine sand fraction (0.02 to 0.1mm) is less than 68%, erodibility varies approximately as the 1.14 power of M, but prediction accuracy is improved by adding information on organic matter content (OMC), soil structure and profile permeability class. Thus, for soils containing ≤ 68% silt plus very fine sand, erodibility K in SI units becomes [16]:

$$K = \frac{0.00021 x m^{1.14} x (12-a) + 3.25 x (b-2) + 3.3 x 10^{-3} (c-3)}{100} \tag{4}$$

where: m = the particle parameter derived as follows:

= (Percent silt + percent very fine sand) (100 – percent clay);

a = the percent organic matter content; b = the soil structure code (very fine granular, 1; fine granular, 2; medium or coarse granular, 3; blocky, platy or massive, 4); c.= the profile permeability class (rapid (150 mmh^{-1}),1; moderate to rapid (50 – 150 mmh^{-1}), 2; moderate, (12-50 mmh^{-1}),2; slow to moderate (5 – 15 mmh^{-1}), 4; slow, (1- 5 mmh^{-1}), 5; very slow, (< 1 mmh^{-1}), 6.
The size of the soil particles for very fine sand fraction = 0.05 – 0.10 mm, for silt content = 0.002 to 0.05, and for clay = < 0.002 m. The soil OMC = 1.72 x % organic C [18].

2.3 Soil Chemical Properties

Organic Carbon contents of the soil were determined using Walkely- Black (1934) Wet Oxidation Method. The Organic matter contents were obtained by multiplying the organic carbon by Van Bremmelon factor or 1.724, based on the assumption that organic matter contains approximately fifty eight percent (58%) carbon [18].
Exchange Sodium percentage (ESP) was calculated using standard equation; while Sodium absorption ratio was (SAR) calculated after exchangeable cations (Ca, Mg, K, and Na) were extracted from the soil with 1N NH_4 OAC solution. Na and K were measured with flame analyzer while Mg and CA were determined using EDTA solution.

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{2+}}+Mg^{2+}} \quad (5)$$

2.4 Statistical Method

The data extracted from fieldwork were processed and analyzed using SPSS software version 17.0 for means, standard deviation, correlation coefficients and regression estimates. Pattern of gully growth in the area was examined using simple regression analysis and curve fittings.

3 Results and Discussion

3.1 Morphormetric Growth Rate

The growth rate for gully length (L) was 0.34 while that of width (W) was 0.18. Linking this data analysis with a previous study on rainfall effect on the same site [19], it is observed that approximately 88% of length increment and 69% of width increment at GU.01 were explained by the duration of causative rainfall [2]. The positive correlation coefficient with rainfall implies that gully length and width increased over time, while the negative coefficient with duration of rainfall indicates that the rate of growth might have fluctuated. The increasing rate was obtained between April and July and in September when rainfall was increasing while the decreasing rate set in from October when rainfall was decreasing [2]. Similar pattern was obtained in GU 02 – 05 but with different growth rates. Given the rainfall pattern of Uyo, minimum growth rates for gullies at the site were 0.31-033m/yr for length and 0.16-0.18m/yr for width of young gullies. Altogether rainfall condition contributed less than 40% (P^2< 40%) of volume of soil loss while 60% of the variance in the volume of soil loss, which was not accounted for in the rainfall model, could be linked to the anthropogenic impact and the properties of the soil of the area.

Mechanical disturbance by rough grading and smoothening of the soil constituted the anthropogenic action at the underground construction site.

3.2 Physical Properties of the Gully Soils

Table 1 shows the physical properties of the soil at the five sample gully sites. Soil of the five gullies recorded almost similar physical properties; only slight variations were observed in most physical properties of the soils at the five gully sites. The highest mean proportion of fine sand was 9.33±3.34% at (GU04) followed by 8.44±2.28% at GU03 while the least was 5.78±0.77% (GU01). Thus, following land grading, the proportion of fine sand in the gully soil was not more than 10%. Distributions of fine sand seem to increase down the slope. GU01 at the crest had the least fine sand; the fine sand content increased in GU02 and GU03 (as the middle slope) while GU04 at the valley bottom had the highest. Similar trend was observed in clay and silt (Table 1). Their percentages increased down the slope with the highest at GU05 and the least at GU 01, however there was no significant difference ($p<0.05$) in the distribution of fine sand, clay and silt among soils of the five gully sites.

The insignificant difference may be attributed to the fact that the five gullies were samples on soils of the same parent material formed under the same vegetation and climate almost at the same time. Hence, the properties are likely to be similar. Texture of the soils was homogenous along the slope positions 20≥CV≤ 30%) [11]. By removing the top soil and vegetative cover, the land-grading exposed the subsoil of the same parent materials. The slight variation may indicate the influence of slope on the physical properties of the soils. Fine particles are most erodible as these are easily transported by run-off than coarse or coarse-grain particles. Run-off mobilized at the crest will run to the valley bottom, hence, accumulate more of eroded fine soil particles at the bottom. The trend for coarse sand was in the reverse of fine sand. It decreased down the slope, showing its resistance to dislodgement and movement from up-slope compared to fine sand. However, coarse sand particles dominated the particles size fraction of the soil. The percentage of coarse sand was highest (86.76±0.58%) at GU.01, followed by 85.67±2.25% at GU.02 while the least was 79.11±5.97 at GU.05. This gives a highly coarse sandy texture.

Coarse particles are heavy and difficult to be transported by running water compared to other particles, hence, erodibility of gully depth may be constrained because erodibility decreases with an increase of large sand grains and rock fragments [5]. The insignificant percentage of silt related to the mechanical removal of topsoil during land grading operations.

Bulk density (BD), as the mass of a unit volume of dry soil (including volume of both solids and voids), indicates the compaction of the soil and depends on the type and nature of the mineral and organic matter content as well as the aggregation of soil constituents. Values obtained in this study were generally high (92 g/cm^3) indicating that these soils were very compacted. Soils at GU01 to GU04 had almost similar but higher bulk density (92 g/cm^3) than that of GU05 (87 g/cm^3, Table 1), reflecting the low compaction of gully at tunnel bottom, which was influenced by deposition of eroded materials. The high compaction of the soil reflected the influence of mechanical land grading (human activities) and the growth of the gully therefore might have been accelerated by the slope differences between the crest and tunnel bottom. The similarity of BD to TS is curious, but may portray the overall dominance of CS against insignificant quantities of

FS and SL in the bulk soil (Table 1).

Total porosity was very low (10 – 9%), non-porous and homogenous except that the large coarse grains which were more at upslope and the crest (GU02, GUO1) (Table 1) than at the trench bottom (GU05, GU04) offered large pore sizes thereby resulting in slightly higher porosity (0.1) than the trench bottom (0.09).

Table 1: Some physical properties of soil at the gully site at underground drainage construction site, Uyo.

Soil Property	GU01	GU02	GU03	GU04	GU05	Overall $\overline{X}$	Sd	CV
Fine Sand, %	5.78	6.67	8.44	9.33	7.78	7.6	1.41	18.50
Clay, %	5.9	6.09	6.39	6.49	11.1	7.194	2.20	30.53
Silt, %	1.57	1.58	1.441	1.6	1.98	1.634	0.20	12.45
Coarse sand, %	86.76	85.67	83.7	82.5	79.1	83.55	2.99	3.58
Total Sand, %	92,53	92.33	92.1	91.9	86.8	91.13	2.43	2.67
Bulk Density, g/cm^3	92.53	92.33	92.1	91.9	86.89	91.15	2.39	2.63
Total porosity	0.1	0.1	0.09	0.09	0.09	0.094	0.01	5.83
Hydraulic conductivity, cm/h	0.433	0.42	0.64	0.94	1.9	0.975	0.65	66.92
Silt/clay ratio	0.06	0.04	0.05	0.04	0.04	0.046	0.01	19.44
Moisture content, %	0.34	0.27	0.24	0.27	0.19	0.262	0.05	20.80
Soil Erodibility,	0.01	0.01	0.01	0.02	0.01	0.012	0.00	37.27

N/B: $\overline{X}$ = Mean of GU 01 to GU 05; Sd = Standard deviation, CV = Covariance

The land grading removed all top soil mass, leaving the subsoil layer rather cohesive as a parent material. The lower total porosity is a reflection of the land-grading equipment compaction and the high bulk density of the exposed sub-layer soils. The lower porosity accelerated rapid accumulation of run-off water and the subsequent discharge transported more fine materials from upslope and crest points to the trench bottom, thus eroding the soil and expanding the gullies.

Hydraulic conductivity (K_s) of the soil was generally low (less than 2cm/hr) and varied spatially along the longitudinal slope (CV = 66%, Table 1). Values of K_s less than 2cm/hr indicates slow conductivity class [3], hence, the exposed subsoil was impermeable. When hydraulic conductivity is low, water easily accumulates and discharges from one point to another, such that much run-off is produced on slope which may erode such soil. For soils with high K_s, water infiltrates into the soil at higher rate and less is left to flow as run-off. The slow K_s is also attributed to the high bulk density and low porosity of the soils. The K_s at the valley bottom was four times greater than K_s at the crest, showing that the material at the bottom trench was deposited sediment and more permeable (K_s= 0.9 –1.5, Table 1) than at the crest and mid slope (K_s= 0.43-0.64, Table 1) which experienced machine compaction. Gully growth on these sites is likely to increase at faster rate since less water infiltrates soil especially on a sloppy land as this site.

3.3 Silt/Clay Ratio

Silt is the least resistant soil particle; soil with 40 - 60% are most erodible [19]. Clay fraction of 9 – 30% makes the soil most susceptible to erosion [21]. The soil at all gully sites are susceptible to erosion (clay ≤ 11%) and both silt and clay are homogenously distributed (CV < 30%). Therefore, silt/clay ratio of the soil was also low (Table 2), and soils of the entire gullies had almost similar value between 0.04 and 0.06 and were spatially homogenous and erodible. Also, the soils can be regarded as young soils that have not attained an advanced stage of weathering, because silt/clay <15 indicates that the soil is young [20]. The soil under reclamation is less than 5 years old, so they are young soil which suggests that the process of gullying and growth of the gullies formed may be active since the soils are still young.

3.4 Soil Erodibility

Erodibility of the soil at the five gully points was almost constant (0.01-0.02) (Table 1) and generally low, which suggests that soil may easily resist erosive force of water if it is kept bare particularly in the sloppy condition. The erosive runoff might have contributed significantly to the growth of these gullies under the derived texture from mechanical land-grading. The preponderance of coarse sands (large grained sands) correlated with (r = 0.186) the low erodibility at the site, since large grained particles are difficult to be displaced by runoff water, hence giving low erodibility [5].

3.5 Chemical Properties of the Soil

Organic matter content and chemical constituents of soils have significant effect on erodibility [3]. Organic matter content (OMC) of the soil at the five gully points were of the range of 2-3% (Table 2). Organic matter content decreased down the slope, with highest range of 0.29 – 0.35% at the trench bottom (GU05), followed by GU04 and GU03, while the least was at the crest (GU01) with 2.4±0.40%. Organic matter influences soil erodibility as the stability of the soil aggregates with low OMC may be loose and easily detached by running water especially for soils of sandy texture [5]. [21] reported that soils with less than 3.5% of OMC was grouped as erodible, thus, the soil are erodible, however, the low OMC (< 10%) makes for decreased erodibility [22] as observed in Table 3. Electrical conductivity (EC) was between 0.01 and 0.03 ds/m (Table 2); specifically, the soil at GU02 had the highest EC (0.03 and 0.02 ds/m) while soil of GU04 had the least (0.012 ds/m). Exchangeable sodium (Na) was between 0.04 and 0.06 Cmol/kg. The highest sodium content was obtained in the soil at GU04 followed by soil along GU03 while soil of the other gullies had similar Na content. Sodium is a dispersing agent that facilitates the dispersion of the soil particles.

For Magnesium (Mg), soil along the crest and middle slope had higher values than soils at the trench bottom (Table 2); also values were higher than those of Na. Mg is a binding agent that reduces detachment action of running water, thereby reducing runoff erosion on soils. The lower the Mg, the lower the cohesion between soil aggregates, hence, the more it is detached by high rainfall impact and the more it is eroded by erosive flow. The exchangeable sodium percentage (ESP) was higher at the middle slope and trench bottom than the crest; this corresponded with the distribution of exchangeable sodium in the soils across the slope (Table 2). ESP shows the proportion of Na to other basic cations in the

soils. High value of ESP indicates high salt content and such soils are easily eroded. Sodium absorption rate (SAR) is another way of expressing the proportion of Na to other cations in the exchange complex. The values (Table 2) were generally low, suggesting that the exchange site was saturated with other basic cations than Na
(BS = 70-88%). The strength of clay (itself non- erodible material) increases as the value of SAR increases with the replacement of Ca and Mg by Na.

Table 2: Some chemical properties of the gully soil

Property	GU01	GU02	GU03	GU04	GU05
Org. M.	2.44±0.04	2.44±0.53	2.67±0.40	2.78±0.52	2.90±0.35
EC	0.02±0.01	0.03±0.02	0.02±0.00	0.01±0.00	0.02±0.03
EA	0.09±0.13	0.85±0.15	1.58±1.07	0.94±0.15	0.90±0.13
K	0.06±0.01	0.07±0.02	0.08±0.04	0.05±0.01	0.06±0.00
Na	0.04±0.00	0.04±0.01	0.05±0.00	0.06±0.00	0.04±0.01
Ca	4.27±0.74	4.69±1.33	0.85±0.37	1.28±0.00	3.41±2.59
Mg	2.35±0.98	2.56±0.00	0.64±0.00	0.85±0.37	1.92±1.11
ECEC	7.61±0.25	8.22±1.35	3.21±1.00	3.19±0.46	6.33±3.60
BS	88.19±1.96	89.50±1.85	53.83±17.27	70.45±3.40	79.62±16.49
ESP	0.54±0.05	0.55±0.20	1.75±0.59	1.89±0.27	1.08±1.04
SAR	0.02±0.00	0.02±0.00	0.04±0.00	0.04±0.00	0.03±0.02

N/B: Org. M., BS, ESP, and SAR are %; EC is in dS/m; EA, K, Na, Ca, Mg and ECEC are in Cmol/kg.

But, with the higher content of Mg^{++} at gully soil (2.5 to 0.64 Cmol/kg, Table 2) and Ca^{++} (4.69 – 0.85 Cmol/kg, Table 2) against the low value of Na^{++}, such replacement sites were saturated and Na could not disperse the compacted soil and clod aggregates. Hence, erodibility was reduced by the cementing action of the base materials (Mg^{++}, Ca^{++}).

3.6 Relationship between Soil Erodibility and other Soil Properties

Soil erodibility is a major soil property that determines how easily a soil surface can be affected by soil erosion; nevertheless other soil properties like organic matter, soil structure, texture (particle size), among others, have some influence on soil erodibility. To assess this impact in the study soil, soil erodibility was correlated with other soil properties. Only a fair but not significant correlation existed between soil erodibility and other soil properties (Table 3).

Table 3: Relationship between other soils properties and soil erodibility

Soil Properties	Correlation Coefficient, r
Fine Sand	0.688
Clay	-0.18
Silt	-0.093
Coarse Sand	-0.186
Total sand	0.173
Bulk Density	0.173
Total porosity	-0.408
Saturated Hydraulic Conductivity	0.721

Silt/clay (SCR)	-0.375
Moisture content (mc)	0.082
Organic matter (OMC)	-0.562
Electrical Conductivity, EC	-0.791
Exchange acidity	-0.171
Potassium	-0.686
Sodium	-0.875
Calcium	-0.519
Exchange capacity base Saturation	-0.223
Exchangeable Sodium Percentage	0.635
Sodium adsorption Ratio	0.559

Specifically, Na had the highest positive correlation coefficient with erodibility of the soil ($r = 0.875$), hence, Na increased soil erodibility. Ks also had high positive correlation coefficient with soil erodibility ($r = 0.721$) which was not significant ($p>0.05$). Other soil chemical properties had values of $r<0.6$ except potassium, EC, ESP. Thus both K_s and Na had higher influence on soil erodibility at this site.

3.7 Relationship between Soil Properties and Gully Morphometric Properties

Only few soil properties had fair relationship with length, width and depth increment, and volume loss of the gullies (Table 4). However, none of the relationship was significant ($p>0.05$), which implies that the soil properties under mechanically graded soil except K_s did not have much impact on gully growth in the area. Therefore where mechanically disturbed soil is bereft of its soil cover, fine sand is lost and only coarse sand remains, the soil property will not produce significant gully growth, clay can combine with OMC to form stable aggregate but as both were low (being reduced by mechanical land-grading), the soil is left erodible but because of binder Mg being higher than Na, the erodibility becomes low.

Table 4: Relationship between other soils properties and gully growth

Soil Properties	Correlation Coefficient (r)			
	L,	W,	D,	Volume loss
FS	-0.223	-0.399	-0.135	-0.269
CL	0.566	0.782	0.703	0.648
SL	0.511	0.73	0.711	0.593
CS	-0.35	-0.442	-0.508	-0.594
TS	-0.565	-0.781	-0.707	-0.646
Bd	-0.564	-0.781	-0.708	-0.646
TP	-0.198	-0.021	-0.249	-0.17
Ks	0.214	-0.399	-0.232	0.089
S/C	0.477	0.084	0.247	0.403
MC	-0.108	-0.446	-0.196	-0.192
Org M	-0.334	-0.709	-0.159	-0.427
Ec	-0.064	-0.034	-0.261	-0.069

Ea	-0.252	0.348	-0.333	-0.134
K	0.009	-0.128	-0.224	-0.031
Na	-0.176	0.137	-0.417	-0.125
Ca	-0.347	-0.758	-0.293	-0.453
Mg	0.067	0.43	0.121	0.153
ECEC	0.067	0.431	0.122	0.154
BS	0.069	0.45	0.098	0.159
ESP	0.02	0.263	0.147	0.081
SAR	-0.052	-0.35	-0.054	-0.121

Observations show the fair correlation coefficients related to horizontal (W) and vertical expansion than longitudinal (L). OMC and Ca impacted on W far more than D and L. Fine sand was < 10% (Table 1) and hence could have significant effect on gully geometry degradation and on soil loss. CL, SL, total sand and Bd highly reduced gully width and depth degradation (r = -5 to -7, Table 1) and so soil loss at the gully site. Their soil loss correlation values (Table 4) gave an average of 64% confirming the previous fact that while rainfall produced 40% explained relationship, the other 60% is related to soil properties and human actions. Also, the low correlation of properties with length is an indication that rainfall/runoff affect gully degradation in length on the slope more that other dimensions.

5 Conclusion

Physico-chemical properties of soil under anthropogenic disturbance by mechanically land-grading at the underground (tunnel) drainage construction site in Uyo , Nigeria, were investigated using standard methods and correlated with erodibility, gully growth and soil loss. Observed data were analyzed using SPSS version 17 package for mean, variance, covariance, spatial variability, correlation and significant differences.

The soil at the banks of the land-graded tunnel from its crest to the bottom was compacted resulting in insignificant fines, predominant coarse sands, high bulk density and low porosity, and very low K_s Texture was highly homogenous all along the depth but Ks showed significant variability resulting in CV = 40% covariance at the bottom trench. Fair but insignificant correlation for Ks (r = 0.72) at the crest/mid slope and high negative correlation (r = -0.875, Table 3) for Na was observed. CL, SL, TS, bulk density and total porosity showed negative and low correlations with gully growth. There was no significant correlation between other physical and chemical properties with gully growth and soil loss. Hence, graded soil properties had low impact on gully growth and soil loss at the construction site.

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