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Assessment of physical and hydraulic properties of soils in badly excavated and degraded site at Agu Awka, Anambra state

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Abstract

This study was carried out to assess the impact of unregulated mining and sand excavation on the physical and hydraulic properties of soils located at Agu Awka in Anambra state, Nigeria. Samples were collected from the lower Elevation (LE) and upper Elevation (UE) sections of the excavated site and the adjacent non-excavated fallowed farmland (control - C). Profile description of the excavated site was carried out using the USDA standard procedure. Disturbed and undisturbed soil samples were collected randomly at two depths (0-15 and 15-30cm) in three replicates to assess the soil physical and hydraulic properties in the Laboratory. The infiltration rate was determined in the field using a double-ring infiltrometer. Data collected were subjected to analysis of variance (ANOVA) using GenStat Release 10.3 DE, means were separated using Fisher's least significant difference (FLSD) at 5% while the coefficient of variation (CV) was used to measure the spread out of the means within the profile. Results obtained showed that soil texture for excavated sites and fallowed farmland were sandy. Bulk density increased with depth while total porosity and hydraulic conductivity (Ksat) decreased with depth. Three master horizons (Ap, AB, & C) which are very deep (21.5m) with colour differentiation (dark red to yellow) and a granular structure having smooth to wavy boundaries were identified. The poor soil physical quality under excavated sites were attributed to adverse impacts of indiscriminate mining and excavation over the years.

Keywords: Saturated hydraulic conductivity; fallowed farmland; sand excavation; degraded sites; unregulated Mining; soil profile

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1.0 Introduction

The need for sand and laterite for building, backfills and road construction is on the increase due to massive infrastructural development in Anambra state. Environmental degradation extends beyond the excavation of both surface and subsurface areas of the soil, disturbance such as excavation or land levelling alter the soil profile by destroying vegetation, root channels and soil horizons which consequently affect the soil profile. (REF)

Mining of some minerals has caused land degradation in the country due to the open-pit method that is commonly used. This method destroys the top layer and the profile of the soiland renders the land uncultivable and derelict. Excavation of laterites, sand, kaolin, gravel, clay etc. for building purposes is common in many parts of Nigeria. Most of the materials excavated were never replaced leaving the areas with hollows and gullies. This has led to the creation of 'badlands' in some areas and in other areas these hollows created are filled with rainwater creating artificial ponds thus causing the degradation of the land. Soil excavation could lead to soil erosion, flooding, waterlogging, loss of arable lands, alteration of soil profile etc.

In Nigeria, over seventy per cent of the population depend on exploiting the soil directly for their long-term livelihood. They extract/exploit the soil in the forms of crop farming, animal husbandry, mining, etc. Many depend on the soil to build their houses while construction companies equally excavate the topsoil for various infrastructural developments. All of these socio-economic activities are known to impact, often negatively, on the condition of the soil, vegetation and water resources (Adewuyi, *et al.,* 2017).

The process of soil degradation as a result of excavation activities for instance includes water and wind erosion, chemical and physical degradation. This consequently brings about changes in the physical, chemical and biological properties of the soil (Suleman, 2014). However, land degradation of terrestrial habitats due to extensive excavation activities often result in loss of natural ecosystem with the associated biodiversity (Ezeaku and Davidson, 2008) leading to geoenvironmental disasters which have become a major environmental concern (Lin *et al.,* 2004). Disturbance such as excavation or land levelling would alter the soil profile by destroying vegetation, root channels and soil horizons which consequently would affect the soil profile. Large mining operations disturb the land by directly removing materials in some areas and dumping waste in others thus changing the topography (Botkin and Edward, 2006). Modifications in land use introduce changes in soil properties and productivity over time (Braimoh and Vlek, 2004**).**

Excavation has caused a reduction in the accumulation of organic matter (Croke and Figrarty, 2001) and temporarily or permanently lowered the productive capacity of the land by weakening the soil structure (Suleiman, 2004) thereby increasing the susceptibility of soils to erosion (Musah, 2013) and subsequent degradation. Excavation activities have caused modifications in the soil physical properties through the activities of heavy machines which leads to an increase in the bulk density of the soil (Saviour and Stalin, 2012). Hydraulic properties reflect on the ability of a soil to retain or transmit water and its dissolved constituents (Van Genuchten and Pachepsky, 2011). When the soil bulk density increases, water movement in the soil is impeded and this is evident in the slow infiltration rate and slow hydraulic conductivity of soils in such sites (Oguike and Onwuka, 2017). Also due to loss of organic matter during excavation, which is as a result of removal of vegetation and topsoil, the particle density of the soil is lowered (Hillel, 2004).

In Agu Awka, the soil is put into many uses driven by the demand for industrialization and development, hence, the incessant excavation of soil within the study area and has resulted in unfavourable soil and environmental conditions. Despite the effect, studies are scanty on the effect of excavation activities on soil properties in Awka, Anambra state. Since soil hydraulic and physical properties are fundamental in making inferences about soil quality and sustainability which facilitates the development of alternatives that can prioritize soil and water conservation and vegetation development and thereby ensuring the increase in agricultural production (Dionizio and Costa, 2018). This study was therefore designed to assess the physical and hydraulic properties of the soils in an excavated site in Agu Awka, Anambra state with specific objectives as:

To characterize and describe the existing soil profile of the excavated site.

To determine the physical properties of soils in response to various depths of excavation.

To determine the hydraulic properties of the soils at various depths of excavation.

To compare the results with those obtained from adjacent non-excavated fallowed farmland.

2.0 Materials and methods

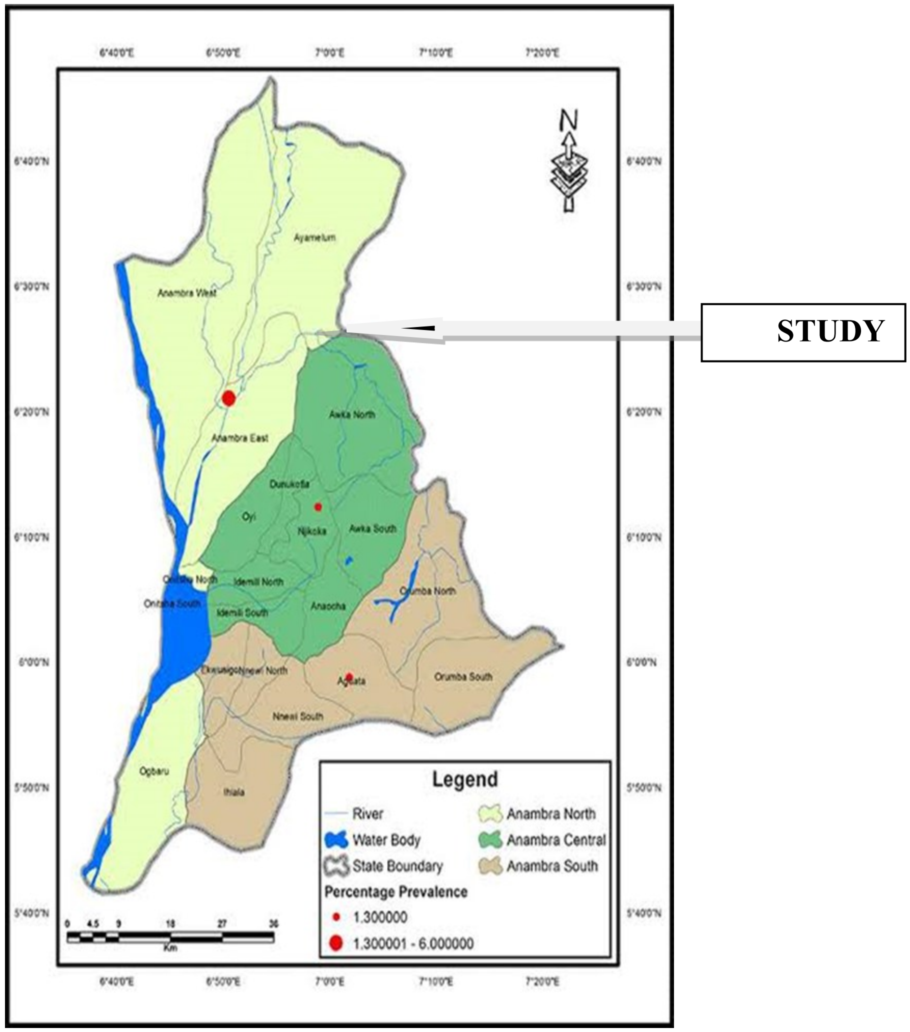
2.1 Site description

The experiment was conducted at the Tipper park, Agu Awka, Anambra state of Nigeria. Awka lies between 6°22ˈN and 7°09ˈE. According to Ezeigwe (2015), Awka is part of the rainforest vegetation with two seasonal climatic conditions, the rainy season and the dry season. The rainy season occurs between April and October and is characterised by wet, humid and sometimes cold weather conditions. The dry season on the other hand spans from November to March with a short extreme and cold weather condition often designated as '*the harmattan period.* Awka has a humid tropical climate with an annual rainfall range of 1,750 to 2,500mm; and an annual temperature range of 28°C to 34°C (Orji and Obasi, 2012).

Geologically, Awka lies within the Anambra Basin whose sedimentary rocks are made up of Nkporo Shale, Mamu formation, Ajali sandstone and Nsukka formation as the main deposits. Its rock types are sandstone, calcareous shale, and shelly limestone in thin bands (Ezeigwe, 2015). The soils of the study location are characterized by very deep well-drained soils and it belongs to the coastal plain sand (Ultisols).

The study area has an undulating topography with gentle to steep slopes. The natural vegetation consists mainly of grasses, bamboo and weeds like mimosa plants, goat weeds etc. The soils are generally weathered or undergoing weathering which is evident from the rock materials lying around on the site and at a corner of the site was an artificial pond. There was an already existing profile pit on the site which was dug as a result of the excavation activities. For this study, the area was divided into three and denoted as C, LE and UE C was fallowed farmland, located adjacent to the excavation site, situated at the crest of the excavated site and is overgrown by weeds. It served as the non-excavated site. It was used as the control for this research. LE was the area adjacent to the artificial pond in the excavated site. It has sparse vegetation and sometimes waterlogged depending on the intensity of the rainfall. LE formed the first part of the excavated site and it was situated at the valley bottom of the excavated site. UE was next to the first part of the excavated site (LE). It formed the second part of the excavation site, had more vegetation than LE but not more than C. On this site were grasses like spear grass, wire weed, bamboo grass and lyme grass. There was no evidence of waterlogging on this site. It has an undulating topography. One of the differences between LE and UE was the gradient. UE had a higher gradient than LE. Together LE and UE make up the excavated site.

Soil samples were collected from C, LE and UE to determine the variability in soil properties under these locations. Soil samples were taken at random from the surface 0-15 cm and 15-30cm in triplicates stored in polythene bags and was used to determine particle size distribution. Undisturbed soil samples were also collected with core samplers (4.5 cm and length 5.0 cm) at the depths of 0-15 cm and 15-30 cm in triplicate designated as R1, R2 and R3, used for the determination of bulk density, total porosity, field capacity and saturated hydraulic conductivity. The second set of undisturbed samples were taken with cores and were used for the determination of gravimetric moisture content.



Source:Google maps, 2018

Fig 2 is a schematic diagram that illustrates some characteristics of the three sites (C, LE, and UE), the two depths (0-15cm and 15-30cm) and the existing profile on the excavated site.

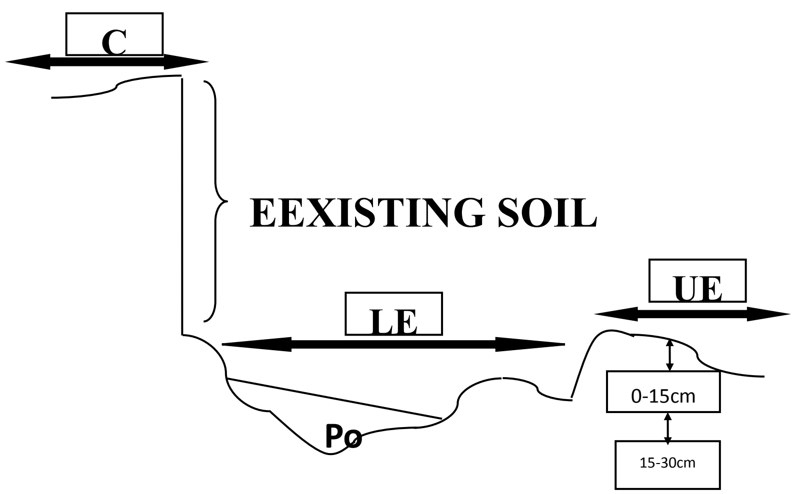


Fig 2: A schematic diagram of the project location showing the sampling sites.

Field work

Soil profile description

For the soil classification, the soil samples were collected from the existing profile pits (after proper cleaning) to determine the physical and chemical properties of the soils, according to USDA (1999) guidelines. Soil samples collected from the horizons were subjected to routine laboratory analysis.

Infiltration rate

The infiltration capacity of the soil was determined using the double-ring infiltrometer according to the method described by Anderson and Ingram (1994). The Infiltration rate (Ir, cm/hr) was plotted against cumulative time (min) on a graph.

Soil Water Content at Field capacity (FC)

The field capacity of the soils was determined using the field method as described by Anderson and Ingram (1994). The percentage gravimetric soil water content at field capacity and volumetric soil water content at field capacity was calculated thus:

Gravimetric soil water content at field capacity = $\frac{W2-W3}{W3-W1} X\ 100$

Where:

Wl = weight of container (g)

W2 = weight of container + wet soil (g)

W3 = weight of container + oven-dry soil (g)

3.2 Laboratory Methods

3.2 1 Soil physical Properties analyses

Particle size distribution of the soils was determined using the Bouyoucous hydrometer method (Gee and Bauder, 1986), using 0.1N Sodium hexametaphosphate $(NaPO_3)_6$ as a dispersant.

Hydraulic conductivity (Ksat) was determined by the constant-head permeameter method (Klute and Dirksen, 1986) and calculated using the transposed Darcy's equation as follows:

Ksat = $\frac{Q \times L}{At \times \Delta H}$

Where Ksat is saturated hydraulic conductivity (cm/h), Q is the steady-state volume of outflow from the soil core (cm^3), L is the length of soil core (cm), A is the cross-sectional area of the soil core (cm^2), t is the time interval (h), and ΔH is hydraulic head change (cm).

The core samples were used to determine the pore size distribution of the soils (Flint and Flint 2002), as well as the total porosity. Bulk density was also determined by the core method (Blake and Hartage 1982). Microporosity was assessed as the volumetric moisture content of the soil at 60cm (water) tension, which was used to determine the total porosity.

Soil chemical Properties analyses

Soil pH was determined electrometrically using a glass electrode pH meter in a soil-liquid ratio of 1:2.5 (Hendershot *et al,* 1993). Soil organic carbon was determined by the wet oxidation method as described by Walkey and Black (1934) and modified by Nelson and Somners (1982). Total nitrogen was determined by the Microkjeldahl distillation method (Bremner and Mulvaney, 1982). %Base saturation (PBS) was calculated as a percentage of the sum of the base-forming cations (Ca, Mg, Na and K) to the CEC of the soil (Agbugba, 2018). Exchangeable acidity was determined by a method described by Mclean (1982). Available phosphorous was determined by the Bray I method using spectrophotometer while exchangeable bases and cation exchange capacity (CEC) was determined by the method described by Anderson and Ingram (1994).

Statistical analyses

Data collected were subjected to Analysis of variance (ANOVA) using GenStat Release 10.3DE, while the significant difference between treatment means was tested using Fisher's least significant differences (F-LSD) at a 5% level of significance. For the samples collected from the already existing profile, coefficient of variation (CV) was used to measure the spread out of the means and was estimated using the equation:

CV = $\frac{S}{Z} \times 100$

Where:

S= Standard deviation which is the square root of the sample variance

Z= Mean of the measured values

Properties with larger CV values are more variable than those with smaller CV values. Oku *et al*. (2010) described a classification scheme for identifying the extent of variability for soil properties based on their CV values, in which CV values of 0-15%, 16-35% and ≥ 36% indicate low (least), moderate and high variability respectively.

3.0 Results and discussion

Particle size distribution

The sand content in all the sampled sites (C, LE and UE) ranged from 89.33 in UE to 91.67% in C (Table 1). However, the lowest sand content was observed in UE (value) while the highest was observed in LE. It was observed that there was a significant difference in the sand content of the site ($P<0.05$). However, there was no significant difference in the sand content at the two depths (0-15 and 15-30cm). This finding did not agree with the findings of Oguike and Onwuka (2017). This shows that land-use change does not easily affect the particle size distribution (Shepherd *et al.,* 2000). The high sand content in the three sites may be attributed to their being derived from the unconsolidated sand deposit which was formed over coastal plain sand and sedimentary rocks (Ojimgba and Amajuoyi, 2018).

The silt content ranged from 1.67% in LE to 3.83% in C (control). A significant difference was observed in the silt content of the site ($P<0.05$), which is in agreement with the result of Oguike and Onwuka (2017). There was no significant difference in the silt content at the two depths (0-15 and 15-30cm).

There was no significant difference in the clay content of the three sites and at the two depths (0-15 and 15-30cm). The textural class of the soils of the excavation site was sandy which is normal for humid tropical soils (Adewale and Adesina, 2011).

Table 1: Particle size distribution of the Different Sites

SITE	% Sand	% Silt	% Clay	Textural class
S1(control)	90.00	3.83	6.17	Sandy
S2	91.67	1.67	6.50	Sandy
S3	89.83	3.17	7.00	Sandy
Mean±S.E.D	90.50±0.49	2.89±0.49	6.56±0.53	
$LSD_{0.05}$	1.35	0.49	NS	

S.E.D: Standard error of differences of mean, L.S.D: least significant difference

Bulk density and Total porosity

The bulk density of the three sites ranged between 1.76 g/cm^3 (in C) and 1.94 g/cm^3 (in UE) (Table 2). There was a significant difference in the bulk densities among the three sites (P<0.05) while the bulk densities were not significantly different with respect to depth. The relatively higher bulk densities recorded in LE and UE compared to C may be due to exposure of subsoil during excavation (Ojimgba and Amajuoyi, 2018; Saviour and Stalin, 2012; Ofunim-Omuruyi *et al*., 2017). It may also be attributed to the use of heavy machinery on the soil during excavation which may have serious implications for subsequent changes in soil properties because gaseous diffusion is made more difficult (Saviour and Stalin, 2012; Adewole and Adesina, 2011). Table 2 showed that the bulk density increased with depth. This could be because the pore spaces decreased within the soil. Heavily compacted soils contain fewer large pores, less total pore and consequently a greater bulk density (University of Minnesota Extension, 2008).

The total porosity (TP) in the study area ranged from 24.91 in LE to 33.65% in C (Table 2). A significant difference was observed in the total porosity of the site (P<0.05). The higher total porosity in C (control) was probably because of the vegetative cover, less or minimal disturbance by heavy machinery and presence of organic materials (Wakene, 2001). This concurred with Brady and Weil (2002) who concluded that the lower the bulk density, the higher the percentage pore space. The decrease in total porosity in the excavation site (LE and UE) may be attributed to the topsoil disturbance (Ibanga *et al.,* 2005), low organic matter as well as the removal of the vegetative cover from the soil including large scale machinery (Ojimgba and Amajuoyi, 2018). There was no significant difference in TP with depth; however, it was observed that total porosity decreased with depth (Table 2). This could be a result of a decrease in pore spaces within the soil (University of Minnesota Extension, 2008).

Moisture content

The moisture content at the sites was generally low. There was no significant difference in the moisture content of the three sites. The low moisture content in the three sites (C, LE and UE) could be a result of the high sand content (Food and Agricultural Organization, 1998), leading to rapid drainage.

Field capacity

There was no significant difference in the moisture content at field capacity among the three sites (C, LE and UE). This could be due to the sandy soil texture (Food and Agricultural Organization, 1998). There was, however, a significant difference in the moisture at field capacity with respect to depth. The moisture at field capacity at 15-30cm was higher than that at 0-15cm. This shows that the moisture at field capacity increased with depth. This could be as a result of the increase in clay content with depth (Ojanuga, 2003) and evaporation effects on the soil surface which may have influenced water retention in the soil (Igwe *et al.,* 2011).

Saturated hydraulic conductivity (Ksat)

Saturated hydraulic conductivity of the excavation site had the slowest saturated hydraulic conductivity (3.6-9.7 cm/hr) when compared to the control (21.6 cm/hr) There was a significant difference in Ksat with respect to both site and depths (0-15cm & 15-30cm). Saturated hydraulic conductivity reduced with what? and this may likely be due to the decreasing organic matter with depth. This observation was a reflection of the influence of OM on soil properties (Oguike and Onwuka, 2017). These differences in hydraulic conductivity with depth could also be a result of an increase in bulk density with depth (USDA-NRCS, 2014) and a decrease in total porosity (pore spaces) with depth (Sari, 2017). These differences in the sites could be a result of structural instability and possible compaction due to mechanical disruption of the pore arrangements (Oguike and Onwuka, 2018) caused by the use of heavy machinery. The slow Ksat observed in the excavation site were similar to the finding of Musah (2013) who said that it was a result of lack of vegetation cover and use of heavy machinery.

Table 2: Physical and hydraulic properties of the soil at the different sites and depths

Site	BD g/cm^3	TP (%)	FC (%)	Ksat (cm/hr)	Infiltration rate (cm/hr)
C (control)	1.76	33.65	13.32	21.6	28.6
LE	1.92	24.91	13.38	9.7	6.2
UE	1.95	26.48	11.24	3.6	6.2
Mean ± S.E.D	1.87 ± 0.05	28.34 ±1.53	12.65 ± 0.91	11.6 ± 4.18	13.7 ± 2.58
LSD $_{0.05}$	0.10	3.41	NS	9.31	7.17
Depth (cm)					
0-15	1.62	29.60	11.75	19.6	-
15-30	1.93	27.09	13.54	3.7	-
Mean ± S.E.D	1.87 ± 0.04	28.34 ± 1.25	12.65 ± 0.74	14.9 ± 3.41	-
LSD $_{0.05}$	NS	NS	1.66	3.41	

S1: site 1 (control); LE & UE: Site 2 and site 3 (excavated site)

S.E.D: standard error of differences of mean; L.S.D: least significant difference; BD: bulk density; TP: total porosity; FC: field capacity and Ksat: saturated hydraulic conductivity.

Infiltration rate (Ir)

There was a clear cut difference in the infiltration rate of the control soil (28.6 cm/hr) and the excavated soils (6.2 cm/hr) Table 2. This observation was in tandem with Oguike and Onwuka (2017), also the slow Ir observed under the excavation site was similar to the findings of Musah (2013) who observed that the loss of vegetative cover from the soil and the large scale use of machinery on such sites led to the loss of organic matter which resulted to the slow Ir. Oguike and Onwuka, (2018) further stated that this slow infiltration rate may be attributed to structural instability and possible compaction due to mechanical disruption of the pore arrangements resulting from frequent excavation activities. The rapid infiltration rate observed in C (control) may be as a result of higher organic materials and vegetative cover which is expected under such a land use system. This is in tandem with the findings of Oguike and Onwuka (2018) who reported that high-level organic matter in bush fallow and forest lands led to low bulk density, high total porosity and favoured transmission of water under such conditions.

From the graph (Figs 3-5), it could be observed that the infiltration rate reduced with time until it reached the basic infiltration. This is because as more water replaces the air spaces, the water from the soil surface infiltrates more slowly and eventually reaches a steady-state (FAO, 1998). The graphs below showed the cumulative time and infiltration rate of the three sites.

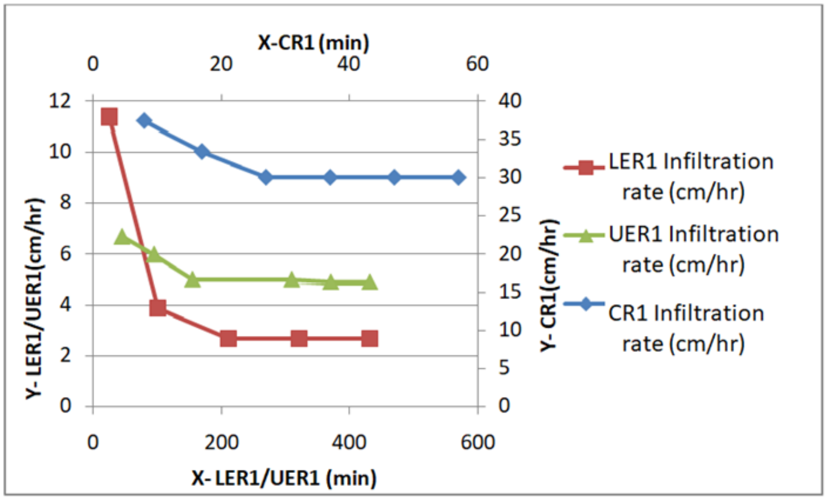


Fig 3: Cumulative time and infiltration rate of CR1, LER1 and UER1

Note: CR1: Control Replicate 1; LER1: Lower Elevation Replicate 1; UER1: Upper Elevation Replicate 1

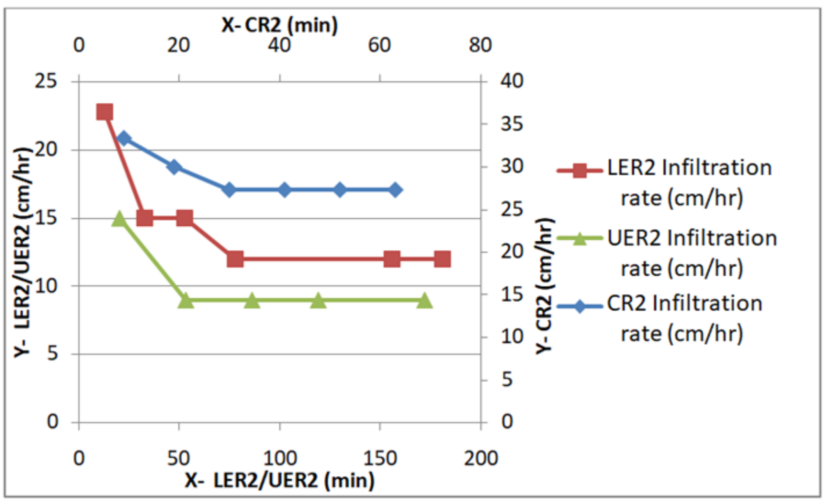


Fig 4: Cumulative time and infiltration rate of CR2, LER2 and UER2

Note: CR2: Control Replicate 2; LER2: Lower Elevation Replicate 2; UER2: Upper Elevation Replicate 2

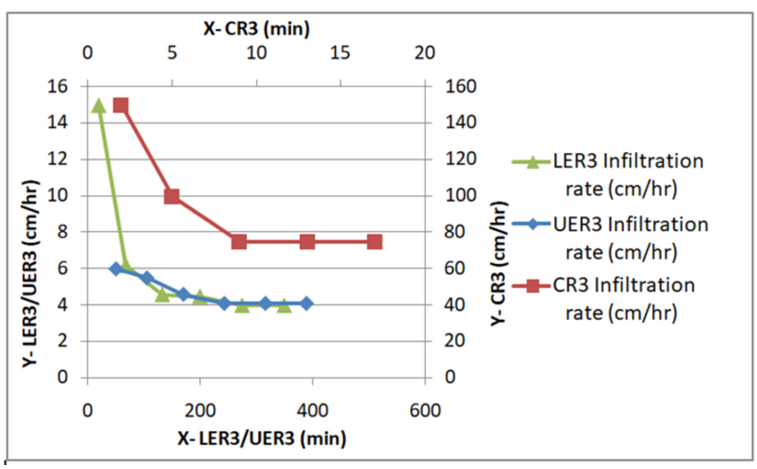


Fig 5: Cumulative time and infiltration rate of S1R3, S2R3 and S3R3

Note: CR3: Control Replicate 3; LER3: Lower Elevation Replicate 3; UER3: Upper Elevation Replicate 3

Soil Morphological Properties

Table 3 showed that the profile has 3 master horizons (Ap, AB, & C), which is very deep measuring about 21.5m which is typical of tropical soils (Johnson *et al.,* 2005). The horizons have a colour differentiation that ranged from dark red to yellow and have a granular structure. The consistency ranges from non-sticky to slightly sticky when wet and loose to friable when moist. The soils of the different horizons are non-plastic and the horizons have smooth to wavy boundaries.

Table 3: *Morphological features of the pedon at the excavated site in Agu-Awka*

Horizon	Depth (cm)	Texture	Moist colour	Consistence	Structure	Horizon boundary
Ap	0-80	SCL	dr (10YR3/6)	fr, ns &np	g	S
AB	80-1100	SCL	dr (10YR 4/6)	Ss&np	g	C
C1	1100-1500	S	y (10YR 8/8)	fr, ns, np, l	lc	W
C2	1500-1700	S	yr (5YR 5/6)	ns, np&vf	lc	W
C3	1700-1900	S	ry (5YR 7/6)	ns, np&vf	hc	S
C4	1900-2150	S	vpb (10YR	vf, ns &np	hc	C

SCL = Sandy Clay loam; S = Sandy; dr = dark red; y = yellow; yr = yellowish red; ry = reddish yellow; vpb = very pale brown; fr = friable; ns = non-sticky; np = non-plastic; ss = slightly sticky; l = loose; vf = very friable; g = granular; lc = loose crumbs; hc = hard crumbs; s = smooth; c= clear; W = wavy

Particle size distribution of the horizons

Table 4 presents the data on soil texture. Sand content was moderately variable (16 ≥ CV ≤ 35%) while silt and clay content were highly variable (CV > 36%) (Oku *et a.,* 2010). The soil texture was sandy clay loam in the first two horizons, sandy in the last four horizons. This agrees with Orji and Obasi, (2012), who reveals that soil texture of South-eastern Nigeria is related to their parent materials. This coarse texture controls the variability in nutrient storage capacity, limit the water holding capacity and roots may grow under sub-optimal soil water due to water deficits (Karuma *et al.,* 2017). Soil texture is the most stable physical characteristic of the soils which influences several other soil properties including structure, soil moisture availability, erodibility, root penetration and soil fertility (Karuma *et al.,* 2017). This is because the texture is a composite of the coarse fraction (sand) and the finer fractions (silt and clay) and an increase or decrease in one component imparts the opposite effect on the other and hence affects physicochemical properties of the soils (Orji and Obasi, 2012.). Clay for example has been reported to interact with organic matter and increased water and nutrient holding capacity (Agbugba, 2018). The silt/clay ratio; an indicator of soil susceptibility to detachment and transportation, was less than the threshold of 0.4 (Karuma *et al.,* 2017) implying moderate resistance to erosion. But the clay content reduced drastically down the profile from the C- horizon which could be attributed to the nature of parent materials, which is derived from the weathered false-bedded sandstones, which are sandy , and the oxidation of the iron liberated during weathering (Orji and Obasi, 2012). The results showed that the clay content ranged between 2.4-22.80% which could be as a result of runoff and erosion (Karuma *et al.,* 2017). The percentage silt content of the pedons was not high. This could be as a result of fluctuations within the depths of pedons (Orji and Obasi, 2012) and indicating the degree of leaching the soil has undergone or are exposed to and the parent material. This could be traceable to severe sheet and gully erosion, resulting in lots of nutrient losses.

Table 4: Particle size distribution and textural class of the pedon at AguAwka

Horizon	Depth (cm)	% Sand	% Silt	% Clay	Textural class
Ap	0-80	65.60	13.6	20.80	SCL
AB	80-1100	67.60	9.60	22.80	SCL
C1	1100-1500	95.60	2.00	2.40	S
C2	1500-1700	73.60	1.60	4.80	S
C3	1700-1900	89.60	5.60	4.80	S
C4	1900-2150	91.60	3.60	4.80	S
Mean	-	80.60	6.00	10.07	-
Std Dev	-	13.19	4.73	9.16	-
CV (%)	-	16.36	78.83	90.96	-

Note: SCL: Sandy clay loam; S: Sand; Std Dev: Standard Deviation; CV: Coefficient of variation

Chemical properties

Table 5 showed that pH, CEC and base saturation were the least variables (CV ≤ 15%). Al, H, Ca, Mg, K, Na, and available phosphorus was moderately variable (16 ≥CV≤35%). Organic carbon and total nitrogen were highly variable (CV ≥ 36%) (Oku and Thomas, 2010). It could also be deduced from the table that the soil is strongly acidic. According to Karuma *et al*. (2017) soils at the surface are strongly acidic (5.1-5.5) while soils at the sub-surface are very strongly acidic (4.5-5.0) which has been recorded in many eroded soils (Orji and Obasi, 2012). The basic element that usually influences aggregation gets easily lost when soil reaction is in an extremely strong acidic range (Orji and Obasi, 2012). The low to very low level of organic matter content is the ideal situation in the humid tropics due to the rapid mineralization of organic matter resulting from high temperatures. Another possible reason could be high leaching and severe sheet erosion, which are evident in the study area. Tillage operations and the depletion of nutrients elements by the very high concentration of arable farming could be another cause of low organic matter content in the area (Orji and Obasi, 2012). The low level of exchangeable bases in the soil is an indication of heavy leaching of the soil nutrients. The leaching of calcium and magnesium are largely responsible for the acidity observed in the soil. High leaching rate is favoured by high rainfall, coupled with the porous nature of the soils due to their texture and the parent materials. The cation exchange capacity (CEC) and the pH were low. (Orji and Obasi, 2012) referred to these soils as low activity clay (LAC) soils, probably as a result of their low (CEC).

Base saturation was >20% but <70% which could be rated as medium-fertility (Agbugba, 2018) (Table 5). Low base saturation levels may result in very acid soils and potentially toxic cations such as Aluminium from the soil (Karuma *et al.,* 2017). They further stated that poor cultivation practices, poor soil and water conservation and inadequate supply of fertilizer to replenish nutrients removed by crops among others can contribute to low-level bases in most soils. According to (Karuma *et al.,* 2015), a relatively high base saturation of 70 to 80% should be maintained for the good performance of most cropping systems. The moderate base Saturation of the soils as shown in the Ap -horizon (Table 5) could be attributed to properties inherited from the parent materials (Orji and Obasi, 2012). The low value of available phosphorus recorded in all the soils could be attributed to strong weathering and low pH. Study by Orji and Obasi (2012) showed that the low available phosphorous content of soil is caused by weathering and low pH of the soil. The parent materials of these soils could as well be poor in phosphorous. Low available phosphorus in the surface and subsurface layers of the pedon may also be attributed to the low soil pH (< 5.8) observed.

Table 5: Some chemical properties of the Horizons within the profile pit at the excavation site

Horizon	Depth (cm)	pH	OC %	EXCH. ACIDITY Al^{3+}	H^+	TN%	EXCH. CATIONS ($cmolkg^{-1}$) Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	BS%	AvailP ($mgKg^{-1}$)
Ap	0-80	5.47	0.19	0.70	0.20	0.017	1.20	0.60	0.12	0.06	2.85	68.1	1.10
AB	80-1100	5.16	0.13	0.80	0.40	0.012	1.00	0.40	0.07	0.05	2.74	56.2	0.84
C1	1100-1500	4.65	0.0059	0.90	0.50	0.005	0.80	0.80	0.15	0.11	3.26	57.0	0.56
C2	1500-1700	4.36	0.25	1.00	0.40	0.02	1.00	0.80	0.08	0.05	3.33	57.9	0.52
C3	1700-1900	4.45	0.23	1.20	0.70	0.02	1.20	0.60	0.10	0.07	2.97	46.1	0.61
C4	1900-2150	4.32	0.23	1.20	0.50	0.02	1.20	0.40	0.12	0.09	3.11	58.2	0.57
Mean	-	4.74	0.173	0.97	0.45	0.016	1.07	0.60	0.11	0.07	3.04	57.3	0.70
Std Dev	-	0.47	0.092	0.21	0.16	0.006	0.16	0.18	0.03	0.02	0.23	6.99	0.23
CV (%)	-	9.92	53.28	21.65	35.56	38.12	17.12	30.00	27.27	28.57	7.57	12.20	32.86

Note: OC: organic carbon; TN: total nitrogen; CEC: Cation exchange capacity; BS: base saturation; Avail P: Available phosphorus; Exch. Acidity: Exchangeable acidity; Exchcations: Exchangeable cations: Std Dev: Standard Deviation; CV: Coefficient of variation

The high bulk density, low total porosity, slow hydraulic conductivity and slow infiltration rate in LE and UE of the excavated site suggests that the soil is compact.. The study on the profile reveals that the soils are deep (21.5m), moderately acidic (pH 4.32-5.47) and low in organic matter and exchangeable bases. The physical and hydraulic properties of the excavation site revealed that excavation activities on the site have exposed the soil surface to and increased its susceptibility to erosion by wind and water which is evident in the washing away of the A-horizon in the site.

4.0 Recommendations

It is recommended that further disturbance on the site by the use of heavy machinery be prohibited especially when the soil is wet. There is a need for some land reclamation activities like draining the artificial pond, construction of surface or underground drainage systems and cultivation of vetiver grass which can reduce further washing away of the topsoils of the excavated site. It is very important to create roadside drains during road construction as well as proper town planning to avoid blocking natural drains which could lead to excessive runoff/soil erosion.

. It is also recommended that appropriate and integrated land management options (some conservation practices like crop rotation, cover cropping, agroforestry, mixed farming) be undertaken at the excavation site to sustain agricultural productivity while protecting the environment.

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