Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 4, 2018
PRINT ISSN 2284-7995, E-ISSN 2285-3952

RELATIVE EFFECTIVENESS OF LAND USE SYSTEMS IN IMPROVING THE ORGANIC MATTER AND PHYSICAL PROPERTIES OF SOILS IN IKWUANO SOUTH EASTERN, NIGERIA

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Abstract

The relative effectiveness of land use systems in improving the organic matter and physical properties of Ikwuano soils were evaluated. The study was conducted on an excavation site, a forest land, bush fallow land of five years, a refuse dump as well as that of the continuously cultivated land. However, organic matter content was significantly high on the refuse dump site and also clay content was high in excavation site, while sandy loam dominated other land use systems. Bulk density and micro porosity values of the soil under different land use systems increased with increase in depth. Also, total porosity and hydraulic conductivity decreased with increased in depth. Therefore, the variations between bulk density and total porosity is attributed to the results of organic matter obtained on refuse dump, bush fallow land, forest land as well as continuously cultivated land use systems. Under excavation land use, the soil was (P<0.05) more compact than other land use systems and this was due to low bulk density. However, refuse dump site (RD) gave significantly the highest values of soil organic matter and physical properties than the other land use systems at the various soil depths, whereas excavation site gave statistically the least value in the order : RD>FL>BF>CC>EX.

Key words*: *land use systems, soil physical properties, organic matter, Ikwuano, Nigeria

INTRODUCTION

The Land use system involves the modification, arrangements as well as activities and inputs which people undertake in certain land cover type to produce food and raw materials, as well as to change or maintain such land. Modification in land use, therefore, brings about changes in soil properties in addition to productivity overtime [7]. According to [24], land use can be derived from the practice of designating permitted use of land based on mapped zones and which dissociates one set of land use from another.

Land use systems affect the distribution as well as provision of plant nutrient elements in the soil. This is due to the direct change in soil properties which also influenced the soil biological activities [9]. However, urbanization which includes housing, industry, commercial enterprise, roads and so on, is a form of land use system [5], incuding continuous cropping, bush fallowing [2] and refuse dump site [4].

In addition, [36] observed an effective and positive modification of the soil physical properties by the forest land use system. This, therefore, helped to develop the tree biomass and also had brought about increase in availability of the plant nutrients [16]. The degradation of soil properties is usually attributed to the conversion of forests and pasture land to crop land. This has caused a drastic change in the distribution and stability soil aggregates. Continuous cropping decreases aggregate stability of soils thereby increasing the bulk density [8].

The excavation activities degrade the environment and pose a serious threat to the lives of residents around the site [11]. The excavations are done without any attempt to reclaim the exposed surfaces on the sites, leaving wide holes where water accumulates. In some places where the water table is high, artificial ponds can be formed. Vegetation is usually the first consult of partial destruction during excavation. The excavation site is characterised by absence of vegetation. Also, damage is more widespread during the time of excavation development as well as operations [11]. However, excavation demands the use of machines, whose emphasis is on the natural environment such as soil compaction, increased rate of leaching, soil erosion and depletion of soil fertility [30]. Excavation sites are also characterized by destruction of natural landscape, creating open space in the ground and generating heaps of sand wastes that cannot be easily disposed off [11]. Excavation has drastically reduced the organic matter accumulation in the soil, and as well decreased soil porosity [35] and increased bulk densities [34].

In addition, the organic component of the soil is made up of plant and animal residues at various stages of decomposition. Also, soil organic matter serves as a reservoir of plant nutrients for crops, improves soil aggregation, increases nutrient exchange between soil and plant and retains soil moisture, reduces soil compaction and increase soil infiltration rate [22]. In the findings of [4], it was observed that soil under forest land had a higher organic matter than soil under continuously cultivated land. They also observed that organic matter decreased with increase in depth. [22] observed a high soil organic matter values in soil from bush fallow land, and the organic matter contents decreased as the depth increased. [4] therefore recorded high organic matter contents from soils found at refuse dump sites.

In Abia State, land is used for many purposes as a result of the increasing demand for industrialization and development, yet studies are scarce on the effects of land use on soil properties. The scarce information has not addressed the issue of comparisons of two or more locations [25]; [32]. Therefore, this study was conducted to investigate the effects of refuse dump site, excavation site, bush fallow, continuous cropping and forest land on the soil physical properties as well as organic matter.

MATERIALS AND METHODS

The Study Area

This research was conducted in Ikwuano Local Government Area of Abia State, Nigeria. This study site located within latitude $5^{0}26'$N and longitudes $7^{0}34'$E [1]. The average population density of this location according to [10] is 491 inhabitants per square kilometre. Therefore, Ikwuano Local Government Area occupied a total area of 281 km^2 [10].

Site Description

Within the location, five land use systems were examined. These are enumerated below: forest land (FL), five years bush fallow land (FB), refuse dump site (RD), continuously cultivated land (CC) and excavation site (EX). The forest has existed for over 60 years with trees such as Iroko, Mahogany, *Gmelina arborea* (Gmelina), *Mangifera indica, Irvingia gabonensis, Treculia africana,* etc. While the five year bush fallow land has trees such as *Dialium guinese* (Ukwa), *Chromolaena odorata* (slam weed), etc.

The continuously cultivated land has been under cultivation with cassava, maize, melon, fluted pumpkin, while the refuse dump site as well as excavation site were used for refuse disposal and mining of laterite for road construction and housing, respectively.

Land Use Systems

[21] classified land use systems into: Agricultural land use system, continuously cultivated land, bush fallow land, forest land and Urban / Industrial land use system.

Agricultural Land Use Systems

This simply entails the use of land for agricultural purposes. It refers to different agricultural practices that land is used for. Such agricultural practices that can be carried out in the land include: continuous cropping, agroforestry, bush fallow system, plantation farming, etc. The type of agricultural use to which a given land in a place is put depends on the prevailing weather condition of the given place.

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 4, 2018
PRINT ISSN 2284-7995, E-ISSN 2285-3952

Continuously Cultivated Land

This is a land that has been put under constant cultivation for crops. The land is used for cultivation of temporary crops or forage for pasture.

Bush Fallow Land

The bush fallow land is described as that piece of land which has been previously cultivated for a considerable period of time and is then left under natural or uncultivated for a longer period to restore the fertility of the soil [19] due to the need to plant up a bigger land area to produce more food, the long fallow periods have Shrank to a few years. The reason is due to the increasing population and its attendant decline in land available for bush fallow system [3]. Bush fallow land is dominated by herbaceous weed species which include, *Chromolaena odorata, Pentaclethra macrophylla, Calopognium mucunoides,* etc. Bush fallow land helps in restoration of soil fertility, serves as a source of raw materials for crafts, medicine, etc. [19] and helps to protect the soil from erosion and moisture loss [22].

Forest Land

[39] defined forest land as a minimum area of land of 0.05 – 1.0 hectare with tree crown cover of more than 10 – 30 percent with trees that have the potential to reach a minimum height of 2 -5 meters at maturity. According to [12], Forest includes natural forests and forest plantations. Forest lands are often home to many animal and plant species and biomass per unit area is high compared to other vegetation communities. Forest land is dominated by trees like *Gmelina arborea* (Gmelina), *Mangifera indica, Irvingia gabonensis, Treculia africana,* etc.

Excavation

This is a site used for mining of minerals or materials like laterite, limestone, etc. The excavation activities degrade the environment and become a serious problem to the lives of residents around the site [11]. The excavations are done without any attempt to reclaim the exposed surfaces on the sites, leaving wide holes where water accumulates. In some places where the water table is high, artificial ponds can be formed. Vegetation is usually the first consult of partial destruction during excavation. The excavation site is characterised by absence of vegetation. Damage is more extensive at the time of excavation development and operations [11]. Excavation requires the use of machines, which stress on the natural environment such as soil compaction, increased rate of leaching, soil erosion and depletion of soil fertility [30]. Excavation sites are also characterized by destruction of natural landscape, creating open space in the ground and generating heaps of sand wastes that cannot be easily disposed off [11].

Excavation has drastically reduced the rate of accumulation of organic matter in the soil, decreased soil porosity [35] and increased bulk densities of soil [34].

Refuse Dump Site

This is a site for the disposal of waste materials by dumping or burial. It is the oldest form of waste treatment. Refuse dumpsites have been the most common methods of organized waste disposal and remains so in many places around the globe. In developing countries, open dumpsites are commonly used due to low budget for waste disposal as well as non-availability of trained man power [38].

Solid wastes are generally collected and placed on top of the ground which often becomes breeding grounds for rats, mosquitoes, flies, etc. They generate unpleasant odour and windblown debris [38].

Soil Sample Techniques

Soil sample technique that was used in this study is shown below. Three (3) soil sampling points were selected randomly within the land use systems. Soil samples were collected at 0 – 20 cm and 20 – 40 cm depths using augar. There were a total of six (6) samples collected from each land use system and a grand total of thirty (30) bulk samples from the five (5) land use systems. Also, two (2) core soil samples were collected from at 0 - 20 cm and 20 – 40 cm depths from the sampling points. A total of six (6) core soil samples were collected and analyzed for. Soils from similar sampling point were later bulked together to form ten (10) samples in all. These samples were used to determine the physical properties of soil in this study area

Soil Sample Preparation

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 4, 2018
PRINT ISSN 2284-7995, E-ISSN 2285-3952

Therefore, the soil samples that were collected with soil augar were air-dried in the laboratory and later sieved through a 2 mm sieve to remove gravels and stones. The sample used for organic matter determination was further crushed, while the samples for mean weight diameter were only sieved through 4.75mm sieve.

The core used to collect the soil samples were covered at the base with a cheese cloth and saturated in water for the determination of bulk density and saturated hydraulic conductivity of the soil.

Laboratory Analysis

These following soil properties were determined: particle size analysis (Bouyoucos hydrometer method) as simplified by [15]. ***Bulk density***; by the method described by [6].

Soil Water Content

Water content at field capacity (FC) as well as permanent wilting point (PWP) were determined using saturation water percentage based estimation methods / models.

The Model are:

FC = 0.1649 + 1.4493

$R^2 = 0.6055$

Pmp = 0.43235P – 7.8315

$R^2 = 0.5965$

Where:

FC = field capacity (%)

PMP = permanent wilting point (%)

SP = saturation water point (%)

Saturation water point is calculated as follows:

$$SP = 100 \times M\theta + \frac{(Msa + Mso)}{Mso}$$

$$\text{Where: } Mso = \frac{100 \times Msa}{100 + \theta r}$$

θr = air – day (resident moisture) (%)

Mθ = mass of water observed (g)

Msa = mass of air – dry soil (g)

Mso = mass of oven – dry soil (g)

However, available water content were subtracted from the values of field capacity (FC) and permanent wilting point (PWP) with the formula (AWC = FC – PWP).

Total Porosity

Total porosity from bulk density value assuming particle density to be 2.65 kg m^3 for mineral soils.

$$Pt = \left[\frac{(1 - Bd)}{Pd}\right] \times 100$$

In addition, macro porosity (Pma) was calculated from volumetric moisture content at field capacity (FC) as described by [18] using the equation below:

Pma = Pt – FC

Micro porosity (PM_1) was calculated as the difference between total porosity and macro porosity.

$Pm_1 = Pt – Pma$

Aggregate Stability

Also, the indices used to determine aggregate stability include the following: mean weight diameter (MWD) and dispersion ratio (DR). The mean weight diameter (MWD) is an index used to measure macro aggregate stability and was determined by the wet sieving method of [14]. It was calculated with the formula as follows:

$$MWD = \sum_{i=1} X_i \; W_1$$

Where:

Xi = mean diameter of each fraction size separated by sieving

W1 = proportion of the total weight sample occurring in the corresponding size fraction

N = Number of size fractions.

The dispersion ratio (DR) as described by [33] was used as an index to determine micro aggregate stability. It determines the ease with which the soil particles will be brought into suspensions by the action of water.

$$DR = \frac{\text{\% silt + clay in water dispersed sample} \times 100}{\text{\% silt + clay in calgon dispersed sample}}$$

Saturated Hydraulic conductivity (Ksat) was determined by the constant head parameter method.

Organic Matter Content

The organic matter of the soil in the study site was determined by Walkely and Black method as modified by [23].

Soil pH

Soil pH was determined in 1:2.5 and water suspension ratio [20].

Statistical Analysis

However, data was collected and analyzed statistically. Also, significant differences between treatment means of various experiments were tested at $P \leq 0.05$ using the Fisher's least – significant differences (F – LSD), according to the procedures of [37]. Therefore, analysis of variance (ANOVA) was used to compare the effects of the land use systems on the measured soil physical properties. In addition, significant difference at 5% level of probability was used. Also, correlation was used to describe the relationship between organic matter and the soil physical properties.

RESULTS AND DISCUSSIONS

Effect of land use systems on soil physical properties

The effect of land use systems on physical properties of soils of Ikwuano, Abia State, Nigeria at 0-20 and 20-40 cm depths was summarised in Tables 1 and 2, respectively. The results from the study show significant differences among the treatment means at P<0.05.

Particle Size Analysis

The results presented in Tables 1 and 2 also summarize the effect of land use systems on the particle size distribution at various soil depths, 0 - 20 cm and 20-40cm, respectively. Generally, the results from the Tables indicated that the soil textures were slightly affected significantly (P<0.05) by the various land use systems. In addition, the results obtained from the refuse dump (RD), bush fallow (BF) and forest land (FL) were statistically similar and having sandy loam texture, while excavation site (EX) and continuously cultivated land (CC) were statistically different (P<0.05) having sandy clay loam and loamy sand at various soil depths, respectively. Also, Tables 1 and 2 show the values of silt which were significantly different and ranged between 2.47% (EX) and 16.47% (CC) for 0-20cm depth and 1.80% (EX) and 16.17% (CC) for 20-40cm soil depth, respectively. The excavation site gave significantly the least results of sand and silt in both Tables. However, the least results of sand and silt in EX as well as the highest values of clay obtained in EX may be due to the exposure of the acidic subsoil during excavation of soils according to [29].

However, textural class of the soils varied from sandy loam to sandy clay loam with sand predominating in all land use. Also, the sandy nature of the soils could be attributed to their being derived from unconsolidated sand deposit which was formed over coastal plain sand and sedimentary rocks [29].

Table 1.Land use systems and their effects on the physical properties of soils of Ikwuano L. G. A. of Abia State (0 - 20 cm Depth)

	Particle Size Analysis										
Land Use System	Total Sand %	Slit %	Clay %	Textural class	Bulk Density Mgm^{-3}	Total Porosity %	Macro Porosity %	Micro Porosity %	Ksat cm/min	MWD mm	DR %
EX	63.60	2.47	33.63	SCL	1.61	39.43	12.10	27.33	0.34	0.33	62.87
RD	72.57	9.73	17.70	SL	1.16	66.30	33.97	32.33	1.08	2.20	30.70
CC	77.13	16.47	6.40	LS	1.48	44.30	25.53	18.77	0.78	1.24	49.97
BF	72.47	8.73	18.80	SL	1.31	50.57	29.50	21.07	0.83	2.03	40.77
FL	71.67	12.07	16.27	SL	1.22	53.83	32.60	21.23	1.05	2.02	40.27
$F\text{-}LSD_{0.05}$	1.44*	2.39*	2.12*		0.22*	0.93*	0.91*	0.27*	0.03*	0.05*	1.15*

FL=Forest land, BF=Four years bush fallow land, RD= Refuse dump site, CC= Continuously cultivated land, EX=Excavation site, SCL=Sandy clay loam, SL=Sandy loam, LS=Loamy sand, Ksat=Saturated hydraulic conductivity, MWD=Mean weight diameter, DR=Dispersion ratio, * = significant at 5% probability
Source: Ojimgba and Amajuoyi, 2018

According to [26], soil with high sand and low clay content have high pollutant leaching potentials, because high percentage of sand on top soil will encourage sandy loam soil. In addition, [4] found that refuse dump site affects the particle size distribution of the soil and the changes lead to sandy loam texture. Therefore, the changes observed in the texture of the soil could be due to the vegetative cover as well as the top soil that were removed during excavation which consequently raised the clay content.

Also, increase in soil depth resulted to an increase in clay content and this is an indication of clay translocation [2], in addition to dissolution as well as leaching of clay materials because of rainfall effect, argillation or clay lessivage and sorting of soil materials [28]. [13] indicated that clay contents of deeper depths increase with increase of cultivation year due to either increase of clay translocation from the surface horizon or exposure of clay by run-off. The significant differences are shown in excavation site and continuous cultivated land.

Table 2.Land use systems and their effects on the physical properties of soils of Ikwuano L. G. A. of Abia State (20 -40 cm Depth)

	Particle Size Analysis										
Land Use System	Total Sand %	Slit %	Clay %	Textural class	Bulk Density Mgm^{-3}	Total Porosity %	Macro Porosity %	Micro Porosity %	Ksat cm/min	MWD mm	DR %
EX	53.90	1.80	44.30	SCL	1.67	32.93	5.03	27.90	0.308	0.24	63.03
RD	71.53	9.30	19.20	SL	1.24	64.30	30.07	33.63	1.016	2.04	30.37
CC	75.80	16.17	8.30	LS	1.55	41.50	22.50	19.00	0.648	1.04	50.70
BF	70.90	9.30	19.80	SL	1.37	48.43	27.20	21.33	0.748	1.55	42.50
FL	71.10	10.10	18.80	SL	1.28	51.83	30.10	21.73	0.976	1.72	41.47
F-$LSD_{0.05}$	1.58*	2.29*	1.14*		0.03	0.19*	0.54*	0.44*	0.020*	0.06*	1.27*

FL=Forest land, BF=Four years bush fallow land, RD= Refuse dump site, CC= Continuously cultivated land, EX= Excavation site, SCL=Sandy clay loam, SL=Sandy loam, LS=Loamy sand, Ksat=Saturated hydraulic conductivity, MWD=Mean weight diameter, DR=Dispersion ratio, * = significant at 5% probability
Source: Ojimgba and Amajuoyi, 2018.

Bulk density, Total porosity, Saturated hydraulic conductivity

Tables 1 and 2 also show significant difference (P<0.05) existing between the bulk density values of the land use systems. The results indicated that refuse dump site (RD) had significantly the least bulk density results of 1.16 and 1.24 Mgm^{-3} which were better than those of the other land use systems for 0-20 and 20-40cm soil depths, respectively. The difference among the mean values were in the following significant order: RD>FL>BF>CC>EX. The significantly (P<0.05) highest bulk density values of 1.67 and 1.61 Mgm^{-3} were observed in the excavation site at 0 – 20 and 20 – 40 soil depths, respectively. This high bulk density values may be due to exposure of subsoil during excavation.

Tables 1 and 2 also summarise the different land use systems and their effect on the total porosity as well as saturated hydraulic conductivity of Ikwuano soils at 0 – 20 and 20 – 40 depths. The results obtained show that there are significant differences existing between the various land use systems. For example, excavation site (EX) recorded significantly (P<0.05) the least total porosity and saturated hydraulic values of 32.93% and 0.308 cm min^{-1} as well as 39.43% and 0.34cm min^{-1} at 0 -20 and 20 – 40cm soil depths, respectively. Refuse dump site gave significantly the highest values of total porosity (64.3 and 66.3%) and saturated hydraulic conductivity (1.02 and 1.08 cm min^-^

[1]), Tables 1 and 2, respectively. The relative improvement in total porosity values was in the order: RD>FL>BF>CC>EX. Similarly, the saturated hydraulic conductivity values was in the following significant order: RD>FL>BF>CC>EX.

The decrease in bulk density and increase in total porosity as well as saturated hydraulic conductivity in the refuse dump site may be attributed to the increase in organic matter content in this land use system. [31] made similar observations. [27] stated that doses of organic matter applied to the soil increased total pore volume, decreased bulk density and favours the transmission of water under saturated condition. [17] also observed that the incorporation of organic wastes statistically increased soil hydraulic conductivity, but the magnitude of increase could be attributed to the rate of application.

The high bulk density and low porosity and hydraulic conductivity observed in excavation site (EX) is similar to the findings of [21]. He, therefore, attributed this to the low organic matter as well as the removal of vegetative cover from the soil including large scale use of machineries on the site.

Water-stable aggregate

Tables 1 and 2 summarise the water-stable aggregate measured by the mean weight diameter (MWD) as indicated in all the land use systems. There were significant differences (P<0.05) existing between the values of the mean weight diameter of the various land use systems as seen in the results. However, the highest mean weight diameter results were obtained in refuse dump site (RD), whereas the rest of the land use systems gave significantly lower values at the various soil depths. In addition, excavation site gave statistically the least value in the order : RD>FL>BF>CC>EX. This may be connected with the lowest organic matter content observed under excavation site (EX). Therefore, the values obtained at the various land use systems indicated that the stability of EX was the lowest followed by CC. The low values of MWD observed may be attributed to tillage with traditional hoeing as well as clean weeding together with reduction in organic matter content [17].

Also, excavation site gave significantly higher dispersion ratio than the other land use systems, while bush fallow (BF) and forest land (FL) had statistically similar values at 0 – 20 and 20 – 40 cm soil depth.

Soil organic matter and pH

Also, Figures 1 and 2 summarize the organic matter as well as pH contents of the various land use systems at soil depths of 0 – 20 and 20 – 40 cm in Ikwuano, Nigeria. Generally, the results from the study show that refuse dump site (RD) had statistically (P<0.05) higher organic matter and pH values than the other land use systems, while excavation site (EX) gave statistically the least values. The relative improvement in organic matter including pH values was in the following significant order : RD>FL>BF>CC>EX.

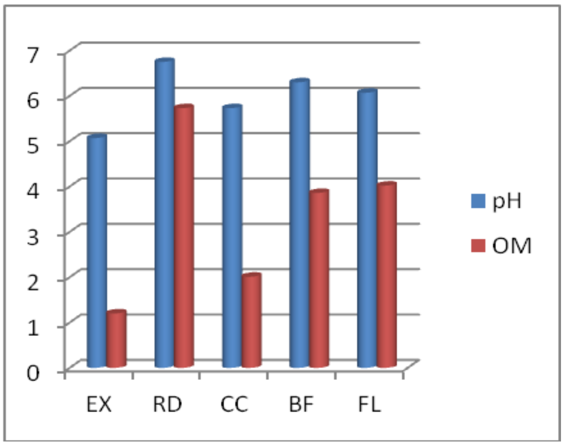

Fig. 1.Organic matter and pH values of soils in the various land use systems at 0 - 20 cm depth in Umudike, Ngeria
Source: Ojimgba and Amajuoyi, 2018.

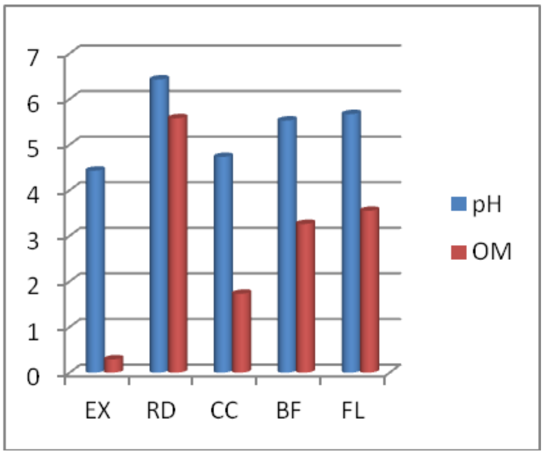

Fig.2. Organic matter and pH values of soils in the various land use systems at 20-40 cm depth in Umudike, Ngeria
Source: Ojimgba and Amajuoyi, 2018.

In the findings of [4], it was observed that soil under forest land had a higher organic matter than soil under continuously cultivated land. They also observed that organic matter decreased with increase in depth. [22] observed a significant high soil organic matter values in the soil from bush fallow land which decreased as the depth increased. [4] recorded high organic matter values from soils found at refuse dump sites, while [4] and [22] observed that the pH of soils under forest land, refuse dump site and bush fallow land ranged from slightly acidic to alkaline and the values decreased with increase in soil depth.

Relationship between Organic Matter and Some Soil Physical Properties

Table 3 shows the relationship between organic matter as well as some soil physical properties under RD, CC, BF and FL. It was observed that organic matter has a positive, strong, significant relationship with total porosity, macro porosity, moisture characteristics, mean weight diameter and bulk density. The table also show that there was no significant relationship between organic matter and soil properties under Excavation site. This could be due to the very low organic matter observed in EX and soil disturbance as well as alteration of soil profile by destroying vegetation, root channels, soil microbes and the soil horizon.

Table 3. Correlation between soil organic matter and some physical properties of soils

Dependent variable	Correlation coefficient (r)
Bulk density (Mg/m^3)	0.96*
Total porosity (%)	0.94*
Percent water (θr) retention at:	
- 0.010 MPa	0.97*
- 1.500 MPa	0.82*
Available water capacity (%)	0.72*
Saturated hydraulic conductivity (cm/hr)	0.75*
Mean weight diameter (MWD)	0.89*

* = Significant at P < 0.05
Source: Ojimgba and Amajuoyi, 2018.

CONCLUSIONS

The effectiveness of land use systems on soil physical properties was evaluated in Ikwuano Abia state, Nigeria. However, the physical properties of the soils evaluated were bulk density, total porosity, aggregate stability, hydraulic conductivity and mean weight diameter.

Also, from the results obtained, it was observed that total porosity, aggregate stability as well as organic matter contents were the properties that mostly influenced moisture content in refuse dump, continuously cultivated land, bush fallow (5years) and forest land.

It was deduced from the results that clay, bulk density and porosity influenced the soil aggregate stability under excavation site. The influence of clay on soil aggregate stability may be attributed to its ability to form slurry when it comes in contact with moisture. Bulk density was also high in the excavation site. The highest organic matter was recorded under refuse dump. From the textural class, the aggregate stability was lowest in excavation site followed by continuously cultivated land.

Refuse dump had higher sand and lower clay as well as silt values. Also, bush fallow had high sand than silt and clay contents. Forest land had high sand content. Excavation site had higher clay than silt. The results also show a high organic matter content in forest land and bush fallow sites, which may be attributed to litter falls and vegetative cover. Organic matter was low in excavation site with a slight acid soil reaction (soil pH) Refuse dump had high porosity also.

Based on the data represented in the study, the research shows that the soil physical properties varied within the different land use systems. Also, the soil particle size distribution recorded that sand sized particles dominated other fractions in excavation site. The textural class ranged from sandy clay to sandy loam, while other land use systems were dominated by sandy loam and loamy sand.

The soil porosity varied with bulk density in the various land use systems. However, high total porosity and low bulk density was observed in refuse dump, five year bush fallow land and forest land. The soils under excavation and continuously cultivated land were observed to be highly erodible. The research point to the fact that the pH of soils ranged from very strongly acidic to moderately acidic.

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