Characterization of Soil Quality in Erosion Prone Environment of Ukpor, Nnewi-South L.G.A. of Anambra State, Nigeria

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ABSTRACT

The study was conducted at Nnewi –South of Anambra State, Nigeria to characterize soil in erosion prone area in order to know nutritional values of the soil to enable farmers employ appropriate measures to conserving the soils for high productivity. Soil auger studies were made at three locations where traverse was cut.Three profile pits designated ECH/UK/ 01 (upper slope) , ECH/UK/ 02 (middle slope) and ECH/UK/ 03 (lower slope) were sited and samples of soils were taken to test for physico-chemical properties of the soils. The results revealed that the soils are deep, well drained , dark reddish brown to reddish brown, and yellowish red of the Munsell color notation. The soil texture in the three pedons have coarse texture that ranged from sandy clay loam to sandy loam, with high percentage of sand which is the reflection of the parent material. The bulk density ranged between between 1.50 – 1.80 $g/cm^{3,}$, soil pH (3.33 – 4.09) indicating very strong acidity status, O.C.(0.28 – 0.89%), O.M (0.48- 1.54%), total N (0.042 – 0.98%), Available P (2.80 – 11.00 $mg.kg^{-1}$), Na^+(0.113 – 270$cmol.kg^{-1}$), K^+(0.036 – 0.087 $cmol.kg^{-1}$), Mg^{++}(0.80-5.60 $cmol.kg^{-1}$), Ca++(0.42 – 10.40 $cmol.kg^{-1}$), EA (0.24 -1.28 $cmol.kg^{-1}$) CEC(3.104 – 16.966 $cmol.kg^{-1}$), and BS (80.28 – 96.06%) indicating low fertility rate of the soil due to heavy leaching and intensive agricultural activities that leads to erosion of the soil to devastating stage, which could be restored by reforestation programme, integrated Nutrient Management Options, and Effective public enlightenment campaign about the advantages of soil conservation for environmental sustainability.

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1. INTRODUCTION

The soil together with water and air constitutes the most important natural resources. It is essential to wisely use this resource for sustainable development and feeding the ever growing world population [1]. Soil degradation due to land mismanagement is a major concern that threatens economic and rural development, especially in third-world countries [2]. Soil quality is one of the most important factors in sustaining the global biosphere and developing agricultural practice [3]. According to Tulu (2002), the global store of arable and grazing land continues to decline through urbanization, unsustainable agricultural practices and deforestation [4]. An understanding of the basic soil properties is essential for developing soil management practices that will maintain the productive potential of a soil. This is particular true of the tropical soils with inherent properties of low cation exchange capacity, low organic matter content, low water holding capacity and structural instability which make them vulnerable to soil erosion.

The subject of soil erosion and its associated menace have become a matter of concern in Nigeria today. It has undoubtedly become known as a potential environmental hazard to almost every communities in Nigeria. This menace affects soil properties and the potential of soil resource in many communities all over the federation are being destroyed. The knowledge of the soil and land use capacities is the bedrock of any modernization process in agriculture. Hence the assessment of the soil properties and classifications in Umuohama community, Ukpor, Nnewi South-East Local Government in southern part of Anambra that farmlands, valuable crops, homes have been lost due to sheet and gully erosion. This study then focuses on knowing the character of soil in order to suggest possible remedies to minimize soil erosion menace to enhance agricultural productivity.

2. MATERIALS AND METHODS

2.1 The Study Area

Nnewi South is a Local Government Area in Anambra State, south-central Nigeria. Its population is approximately 1 million. Ukpor is the headquarters of Nnewi South. Other towns that make up the local government include Ekwulumili, Amichi, Azigbo, Unubi, Osumenyi and Utuh. Others are Ezinifite, Akwaihedi, Ogbodi and Ebenator. Latitude of Nnewi: Latitude of Nnewi: 61'0.012"N, and Longitude of 655'0.012"E.

2.2 Field Study

The field work was conducted for 3 day between 22 – 24th July 2010 with reconnaissance survey for familiarization with the terrain of the study area. Profile pits were sited based on available land use of the area, the topography and soil distribution which was determined by auguring along the topo-sequence. Three profile pits were sited along the transverse to include the designation : ECH/UK/01 (Upper slope), ECH/UK/02 (Middle slope), and ECH/UK/03 (Lower slope). Soil samples were collected for routine analysis. Soil samples were collected from the three types of soils categorized according to depth. soil depth category of 01: 0 - 25, 25 – 43, 43 – 67, 67 – 100, 100 – 136, and 136 – 190 cm ; 02: 0 -20, 20 – 42, 42 – 64, 64 – 89, 89 – 115 cm and 03: 0-16, 16 – 48, 48 – 81, 81 – 116, 116 – 177cm. The soil samples were bagged in 350 cc sampling bag, labeled and transported to the laboratory for analysis. Soil samples were collected from the profile pits at different horizons starting from the bottom to avoid contamination from the top soil at different depths. Samples soil well labeled were sent to soil science laboratory, Federal College of Land Resources Technology, Owerri, Imo State, Nigeria.

2.3 Laboratory Analysis of sampled soils

Mechanical analysis of sampled soils were performed by dry sieving [5]. The particle size distribution was determined by the hydrometer method in which 50 g of sieved air dried soil was weighed into 250 ml beaker and 100 ml of calgon added and allowed to soak for 30 min. It was transferred to a dispersing cup and the suspension stirred for 3 min with mechanical stirrer. The suspension was transferred to a sedimentation cylinder and filled to the mark with distilled water. A plunger was inserted and used to mix the content thoroughly. The stirring was stopped and the time recorded. The soil pH was determined in water using a glass electrode pH meter. Organic carbon was determined by oxidizing soil sample with dichromate solution and later titrated with ferrous sulphate solution [6]. The total nitrogen was determined using micro-kjeldahl method and the available phosphorus colorimetrically by the molybdenum blue method [7]. The exchangeable cations were extracted by leaching 5 g of soil with 50 ml of ammonium acetate at pH 7. The potassium and sodium in the leachate were determined with a column model 21 flame spectrophotometer while the calcium and magnesium were determined with atomic absorption spectrophotometer. The exchangeable acidity was determined by adding barium chloride buffer solution to soil sample and titrated against 0.1 N HCl. Above all , Percentage base saturation (% BS) was calculated by expressing the exchangeable Na and K as percentage of CEC. This is expressed as :

$$= \frac{\textbf{Sum of exchangeable base x 100}}{\textbf{Cation exchange capacity}} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

3. RESULTS AND DISCUSSION

The results of the physical and chemical properties of the soils studied are presented in Table 2, 3, and 4 and are expressed as pedons ECH/UK/O1 through ECH/UK/02 and ECH/UK/03. And Fig.1: Fig.2, and Fig. 3 show Variations of Physico-chemical Properties in various Depths of Soil Profile (ECH/UK/01), (ECH/UK/02), and (ECH/UK/03). Fig4: shows variations of Mean Values of Physico-chemical Properties in Different Toposequence.

Table 1. Characteristics of the study area

Characteristics	Description
Mean annual rainfall (mm)	1850
Rainfall range (mm)	1700 -2000 maximum
Max.Temperature (^{0}C)	35
Bioclimate	Rain forest
Soil type	Sedimentary origin with sandstone
Geology	Fine coarse sandstone
Farming System	Mixed farming
Topography	Flat to greatly rolling landscape

Table 2. Physico-chemical Properties of Soil Profile (ECH/UK/01)

Soil Properties	Soil Profile (cm)						Mean
	0-25	25-43	43-67	67-100	100-136	136- 190	
Sand(%)	75.74	75.74	75.74	69.74	69.74	67.74	**72.40**
Silt (%)	6.00	4.00	10.00	2.00	2.00	2.00	**5.2**
Clay(%)	18.26	20.20	14.26	28.26	30.26	30.26	**23.58**
BulkDensity(g/cm^3)	1.50	1.50	1.65	1.65	1.65	1.65	**1.6**
Texture	S.L	S.C.L.	S.L.	S.C.L.	S.C.L.	S.C.L.	**S.C.L**
pH(Water)	4.41	4.86	4.99	4.69	5.11	5.13	**4.87**
pH(Kcl)	3.70	4.04	4.10	3.80	4.28	4.36	**4.05**
Organic C(%)	0.61	0.53	0.48	0.43	0.32	0.28	**15.6**
Organic M (%)	1.06	0.92	0.83	0.74	0.55	0.48	**27.48**
Total N (%)	0.084	0.056	0.056	0.042	0.028	0.042	**0.05**
Available P(mg.kg^{-1})	8.60	6.00	5.50	2.28	3.60	6.20	**5.36**
Na^+ (cmol.kg^{-1})	0.183	0.174	0.210	0.200	0.131	0.191	**6.53**
K^+ (cmol.kg^{-1})	0.067	0.046	0.056	0.046	0.046	0.061	**0.05**
Mg^{++} (cmol.kg^{-1})	4.80	1.20	2.00	5.60	1.60	2.40	**2.93**
Ca^{++} (cmol.kg^{-1})	10.00	2.00	2.80	10.40	2.40	3.20	**5.13**
^{EA} (cmol.kg^{-1})	1.00	0.84	0.72	0.72	0.28	0.24	**0.63**
CEC (cmol.kg^{-1})	16.05	4.26	5.79	16.97	4.46	6.09	**8.94**
BS(%)	93.77	80.28	87.56	95.76	93.72	96.06	**31.63**

Source: Fieldwork, 2010

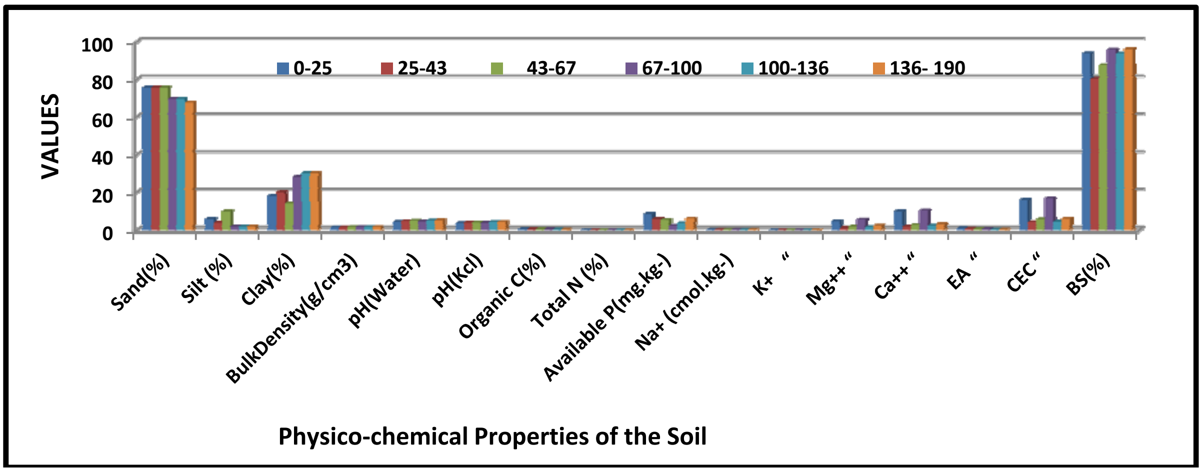

Fig. 1: Variations of Physico-chemical Properties in various Depths of Soil Profile (ECH/UK/01)

Table 3 : Physico-chemical Properties of Soil Profile (ECH/UK/02)

Soil Properties	Soil Profile Depth (cm)					Mean
	0-20	20-42	42-64	64-89	89-115	
Sand(%)	75.74	65.74	65.74	63.74	63.74	**66.94**
Silt (%)	8.00	10.0	8.00	8.00	6.00	**8.00**
Clay(%)	16.26	24.26	26.26	28.26	30.26	**25.06**
Bulk Density(g/cm^3)	1.68	1.81	1.74	1.68	1.60	**1.70**
Texture	S.L.	S.C.L.	S.C.L.	S.C.L.	S.C.L.	**S.C.L.**
pH(Water)	4.37	4.71	4.84	4.69	5.15	**4.75**
pH(Kcl)	3.68	3.99	3.96	3.33	4.90	**3.97**
Organic C(%)	0.68	0.56	0.51	0.40	0.28	**0.49**
Organic M(%)	1.08	0.97	0.87	0.69	0.48	**0.82**
Total N (%)	0.070	0.084	0.056	0.056	0.42	**0,13**
Available P(mg.kg$^-$)	6.40	8.10	6.60	6.80	3.80	**6.34**
Na$^+$ (cmol.kg$^-$)	0.148	0.148	0.270	0.113	0.210	**0.18**
K$^+$ (cmol.kg^{-1})	0.087	0.051	0.046	0.041	0.051	**0.056**
Mg^{++} (cmol.kg^{-1})	1.60	1.20	2.40	1.20	1.60	**1.6**
Ca^{++} (cmol.kg^{-1})	2.80	2.40	2.40	2.80	3.20	**2.72**
^{EA} (cmol.kg^{-1})	1.28	0.40	1.04	0.96	0.32	**0.8**
CEC (cmol.kg^{-1})	5.915	4.199	6.156	5.114	5.381	**5.353**
BS(%)	78.36	90.47	83.11	81.23	94.05	**85.444**

Source: Fieldwork, 2010

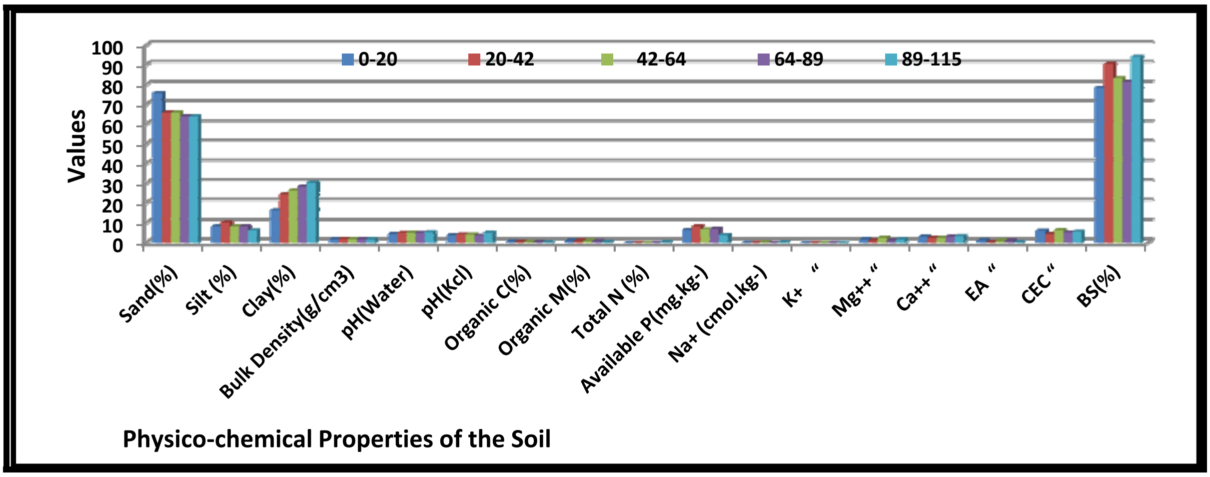

Fig 2: Variations of Physico-chemical Properties at various Depths of Soil Profile (ECH/UK/02)

Table 4 : Physico-chemical Properties of Soil Profile (ECH/UK/03)

Soil Properties	Soil Profile Depth (cm)					Mean
	0-16	16-48	48-81	81-116	116-177	
Sand(%)	75.75	75.74	73.74	75.74	69.74	**74.142**
Silt (%)	10.00	8.00	10.00	6.00	8.00	**8.4**
Clay(%)	14.26	16.26	16.26	18.26	22.26	**17.46**
Bulk Density(g/cm^3)	1.50	1.50	1.62	1.62	1.60	**1.568**
Texture	S.L.	S.L.	S.L.	S.L.	S.L.	**S.L.**
pH(Water)	4.44	4.63	4.80	4.90	5.28	**4.81**
pH(Kcl)	3.84	3.68	3.68	4.00	4.50	**3.90**
Organic C(%)	0.89	0.83	0.77	0.43	0.35	**0.654**
Organic M(%)	1.54	1.43	1.33	0.74	0.60	**1.128**
Total N (%)	0.098	0.084	0.098	0.042	0.042	**0.073**
Available P(mg.kg^{-1})	10.40	8.60	11.0	5.80	5.80	**8.32**
Na$^+$ (cmol.kg^{-1})	0.191	0.240	0.174	0.183	0.157	**0.189**
K$^+$ (cmol.kg^{-1})	0.067	0.056	0.046	0.041	0.036	**0.049**
Mg^{++} (cmol.kg^{-1})	1.60	1.60	1.20	0.80	2.00	**1.44**
Ca^{++} (cmol.kg^{-1})	2.80	2.40	3.20	1.60	2.40	**2.48**
^{EA} (cmol.kg^{-1})	0.88	0.36	0.80	0.48	0.24	**0.56**
CEC (cmol.kg^{-1})	5.538	4.626	5.421	3.104	4.833	**4.704**
BS(%)	84.11	92.22	85.24	85.54	95.03	**88.428**

Source: Fieldwork, 2010

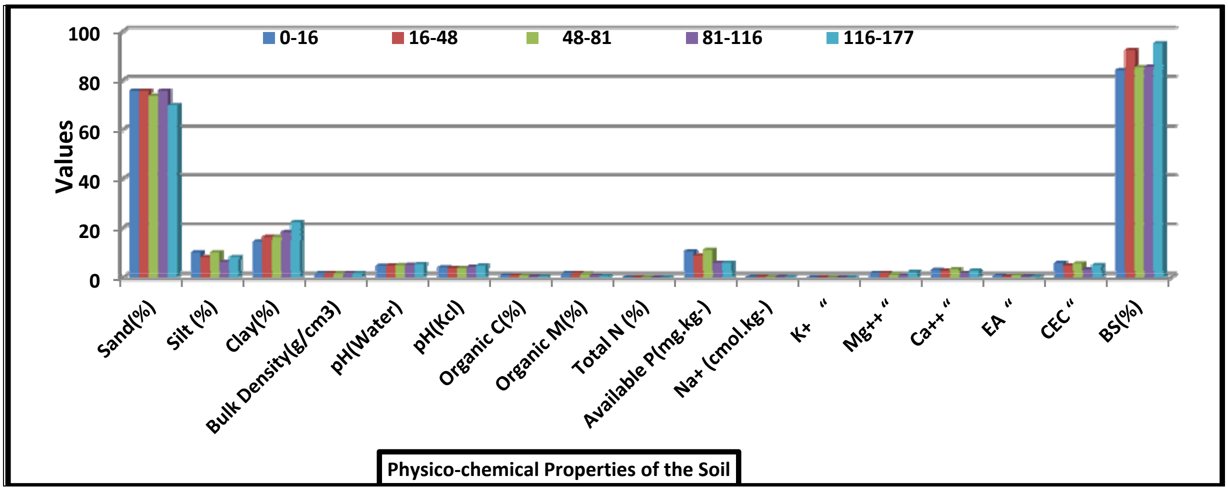

Fig. 3: Variations of Physico-chemical Properties of Soil Profile in the Lower slope (ECH/UK/03)

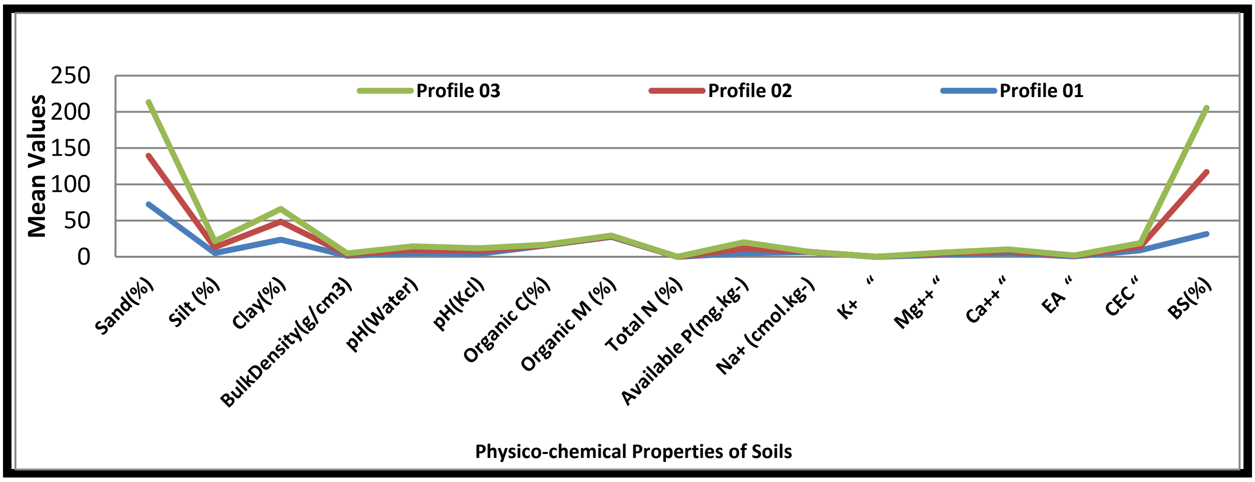

Fig.4: Variations of Mean Values of Physico-chemical Properties in Different Toposequence

3.1 Soil Physical Properties

3.1.1 Soil Texture

This is the relative proportion of the various soil separates sand, silt, and clay that make up the soil classes [8]. From the results, the sand content of all the samples are generally very high ranging between 63.74 – 75.74% , with ECH/ UK /01 and ECH/UK/ 03 having the highest value of 76% and the lowest being ECH/UK/ 02 with 64% .The silt contents in all the profiles are low ranging between 2 – 10 % that fluctuates among the depths of all the pedons . The clay contents ranged between 14.26 – 30.26 % which shows low to medium. The highest value was recorded in UK 01 and UK 03, but shows no definite trend in pedon ECH/UK/UK01. This is as the result of the movement of clay and other finer materials from the top soils by an overland flow. This result was supported by Akamigbo and Asadu (1986) and Adekayode and Akomolafe (2011) [9],[10]. The problem could be remedied by planting trees to protect the soil from being eroded easily [11],[12].

3.1.2 Bulk Density

This is the dry mass (weight) of soil per of bulk volume [8]. From the results, the bulk density of soil samples are generally moderate, ranging between 1.50 – 1.80 g/cm^3. Mostly, the bulk densities increased with depth. This may be due to recent weathering and deposition of eroded materials in pedon ECH/UK/01. Bulk densities above 1.75g.cm^{-3} for sands are quoted by de Geus (1973) as causing hindrance to root penetration in the soil.

4. SOIL CHEMICAL PROPERTIES

4.1 Soil pH

The soils are generally strongly acidic for pH in Kcl. The pH of the soils ranged between 3.3 – 4.5, indicating extreme acidity, except in one horizon which falls within the range of 4.9 in pedon ECH/UK/O2 which indicates very strong acidic reaction. In most cases, the pH values increased with depth.The results are in tuned with the findings of Akamigbo and Igwe (1990) who observed that low acidity values are recorded in humid soils due soil erosion which is responsible for low to high calcium and magnesium content of the soils [9].

4.2 Soil organic carbon (OC) and Soil Organic Matter(OM)

Soil fertility is closely linked to soil organic matter, whose status depends on biomass input and management, mineralization, leaching an erosion [13],[14]. It is well recognized that soil organic matter increases structure stability, resistance to rainfall impact, rate of infiltration and fauna activities [13]. In ECK/UK/01, OC ranged between 0.28 – 0.61%, OM ranged between 0.48- 1.06 % respectively. In ECK/UK/02 OC ranged between 0.28 – 0.63 % , OM ranged between 0.48- 1.08 % and ECK/UK/03, OC ranged between 0.35 – 0.98%, and OM ranged between 0.60 – 1.54% respectively. The results are consistent with the finding of Morgan (1981) who reported that the organic organic matter and organic carbon in humid soils are generally low due to leaching and severe sheet erosion, burial of top soils by tillage and mineralization of organic matter by high temperature [14].

4.3 Total Nitrogen

The total nitrogen status of any soil is closely associated with the soil organic matter [15]. The results of Total nitrogen in the three pedons ECK/UK/01, 02 and 03 indicated that the values ranged between 0.042 -0.084%, 0.042 – 0.070% and 0.042 -0.092% respectively. The values of Nitrogen of the soils were found to decrease with an increased depths, which was observed to be due to erosion of nitrates on the top soils. This result is consistent with the finding of Graham (2010) in the savannah zone of Nigeria [15]. And the Total Nitrogen in the soils was also as very low compared to the ratings of Esu (1991) [16]. The reduced microbial activities caused by low pH can affect Nitrogen availability in the soil [17].

4.4 Available Phosphorus

The available phosphorus content of the pedons varied between low to medium, with values ranging between 2.80 -11.00 **cmol.kg^{-1}**, with pedon 01 having values that varied between 2.80 – 8.60 **cmol.kg^{-1}**, pedon 02 varied between 3.80 – 8.10 **cmol.kg^{-1}** and pedon 03 varied between 5.80 –11.00 **cmol.kg^{-1}**. Loss of phosphorus are usually due to the removal by crops [19]. In acidic soils, much of the P become fixed up by reaction with iron (Fe^{3+}), aluminum (Al^{3+}), and manganese to form insoluble compounds.

4.5 Exchangeable Bases (EB)

Exchangeable bases in the soils include Na^+, K^+, Mg^{++} and Ca^{++} .The values of sodium (Na^+) in pedon 01 ranged between 0.131 – 0.191 cmol.kg^{-1}, potassium (K^+) ranged between 0.046 – 0.067 cmol.kg^{-1}, magnesium (Mg^+) ranged between 0.80 – 5.60 cmol.kg^{-1}, and Calcium (Ca^{++}) ranged between 1.60 – 10.40 cmol.kg^{-1}. The results showed that the valued of exchangeable based ranged between low to medium values in all the pedon [16]. The results of all the exchangeable bases indices such as sodium , potassium , magnesium and calcium decreased with depths. The results are in consistent with the finding of Akamigbo (1983) who observed low Ca / Mg ratio in the soils of Ukpor. Also, exchangeable bases have been observed as inherently low on the eroded soils of south eastern Nigeria [18]. The low exchangeable bases in the soils show heavy leaching of soil nutrients. According to Enwezor (1981) pointed out that leaching of calcium and magnesium are largely responsible for the development of acidity in the soil due to high rainfall with porous nature of the soil texture and the parent materials [18]. This was supported by Mbagwu (1986) [19].

4.6 Exchangeable Acidity(EA)

Exchangeable acidit.y is a measure of the amount of a soil's cation exchange capacity (CEC) that is occupied by acidic cations. By acidic cations, it is generally mean H^+ and Al^{3+}, but it can also include Fe and Mn cations. Aluminum and iron cations will combine with OH^- ions and take it out of solution, forming an insoluble compound. From the results, it is observed that exchangeable acidity ranged between low and medium (0.24 - 1.28 cmol.kg^{-1}), with higher value recorded in pedon ECH/UK/01 and 02, and 03 having the lowest value.

4.7 Cation Exchangeable Capacity (CEC)

From the results, the values of CEC ranged from low to medium, with values between 3.10 – 16.97 cmol.kg^{-1}. The highest value was found in pedon ECH/UK/01, while pedon ECH/UK/03 recorded the lowest value. The low CEC is suspected to due the type of clay mineral present in the soil.

4.8 Base Saturation (BS)

The results shows that the values of BS were very high ranging between 78.36 – 96.06 %, with pedon ECH/UK/01 recorded the highest value in the lowest horizon, while the lowest value was found in the upper horizon of pedon ECH/UK/02. These results could be due to properties inherited from the parent materials due to soil erosion by rainwater. This was confirmed by Akamigbo and Asadu (1986) who reported that parent materials have a strong influence on total exchangeable bases and total acidity of soils [9].

5. SUMMARY

From the study of soil quality in erosion prone environment, The soil textures are sandy-clay loam to sandy loam. Clay and silt contents are low while sand contents are very high, and the bulk densities are generally moderate. The pH, exchangeable bases, CEC, organic carbon and organic matter contents of the soils are very low due to leaching and intensive agricultural activities that leads to eroding of the soil. Also from the mean values of the physico-chemical properties in different topo-sequence, it was observed that concentration of the soil properties were found in the lower slope than the upper and middle due to soil erosion. Land uses patterns and other landuse practices like arable farming, clean weeding, housing, road constructions, bush burning, tree feeling, sand and stone quarrying and the topography of the area were found to be the major factors of soil erosion in the study area.

6. CONCLUSION

It is then concluded that the soils of Nnewi-South Local Government Area of Anambra State are predominantly sandy loamy in texture with low levels of soil nutritional values such as organic matter, organic carbon, total N, available P and exchangeable cation and CEC that were lost be leaching. The soils were also strongly acidic due to constant wearing away of the top soils by sheet erosion which later resulted to gully that are accelerated by anthropogenic activities. Based on the results of the study, the following soil management strategies are recommended.

7. RECOMMENDATIONS

7.1 Reforestation Programme

A reforestation programme with the planting of exotic trees like eucalyptus, acacia, cashew and gmelina for soil rehabilitation are recommended for the reserve as the tree stands would serve to protect the land degradation and also enrich the soil with available nitrogen.

7.2 Integrated Nutrient Management Options (INMO)

Integrated Nutrient Management Options Crop residue management and seed bed preparation methods can play an important role in sustaining the productivity of these soils for crop production. This can be achieved in reduced tillage systems through the use of crop residue mulches, in sit*u* mulches from cover crops, and/or hedgerow pruning from alley farming. Mulch also protects the soil against high temperatures, soil erosion, and run-off, thereby preventing the breakdown of soil structure and the resultant soil compaction and decreased permeability. Furthermore, mulching increases soil moisture retention and reduces runoff and soil erosion [20],[21]**.**

7.3 Effective public enlightenment campaign

Effective public enlightenment campaign about the advantages of soil conservation**.**

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