Anchor University Journal of Science and Technology (AUJST)
A publication of the Faculty of Science and Science Education, Anchor University Lagos

URL: journal.aul.edu.ng

In AJOL: https://www.ajol.info/index.php/aujst

Vol. 2 No 1, June 2021, Pp. 18 - 28

ISSN: 2736-0059 (Print); 2736-0067 (Online)

EVALUATION OF AGRICULTURAL POTENTIAL OF DEGRADED ULTISOLS IN THE HUMID ECOLOGICAL ZONE OF EDO STATE, NIGERIA

[1]Obaro A., [1]Ugwa I. K., [2]Akinyemi A.O. and [*3]Nnamani O. J.

[1]Department of Geography and Regional Planning University of Benin, Benin City, Nigeria
[2]Department of Chemistry, Federal University of Soa Carlos, Sao Carlos, Sao Paulo CEP 13.565-905, Brazil
[3]Department of Surveying and Geoinformatics, Federal University of Technology, Akure, Ondo State, Nigeria

***Corresponding author:**
E-mail: john.nnamani@gmail.com

Submitted 26 December, 2021
Accepted 01 March, 2021

Competing Interests: The authors declare no competing interests.

ABSTRACT

Background: Many agricultural programs in a different part of Southern Nigeria and indeed Edo State have failed due to a lack of understanding of the soil environment within which these programs are executed.
Objectives: This study was designed to evaluate the agricultural potentials of degraded Ultisols in the humid ecological zone of Edo State. Objectives were set to determine the characteristics of the soil, suggest alternative land use(s), and advise farmers on the best management options for the study area .
Methods: A representative profile was dug at the University of Benin Agriculture farm and Soil samples were collected from the profile horizons. The morphology, physical and chemical properties of the soil were evaluated and analyzed using standard procedures.
Results: The result showed that the soil was generally sandy loam in texture but severely weathered. Analysis of bulk density revealed that the soil could hold and sustain crops for their growth and development. The Soil acidity was high as it ranged from pH 5.3 (subsoil) to 5.7 (topsoil). Furthermore, the exchangeable cations (Na, Mg, Ca, and K) showed no significant variation between the topsoil (0-18cm) and subsoil (18-145cm); and the base saturation was high (84.96-90.00%). Correlation analysis employed to show the relationship between the physical and chemical parameters of the soil revealed that Six (6) soil properties were positively significant while two(2) were negatively significant. .
Conclusions: The soil within the study area needs to be improved to enhance its productivity and harness its full potential to support food production. Therefore the study recommends sound agronomic practices especially erosion control measures and further detailed studies to examine soil quality in specific periods for sustainable land use.

Keywords: Morphology, Ecological zone, Utisols, Soil acidity, Agriculture

INTRODUCTION

Soil varies across different parts of the world and even from one part of a plot of land to another. This variation could be attributed to the nature of the location where they are formed, climatic condition of the area, activities of organism, relief, parent materials and time. According to Oko-Oboh (2014) every soil is suitable for specific purposes therefore using the soil for the purposes they are best suited for is required for precision management and conservation. At any given location, there are aspects of the natural environment such as landform and soil types that are invariant and stable, while others such as temperature, rainfall, and incidence of pests and diseases vary with seasons. Lack of information on both the constant and varied characteristics or aspects of each specific location can frequently influence crop productivity.

Nigeria is privileged to have an agriculturally suitable climate and an abundance of fertile soil.

Out of the 75 percent of suitable agricultural land currently available in Nigeria, only 40 percent is cultivated (Omorogiuwa *et al.,* 2014). According to Azad-Hossain (2013), the humid ecological zone is generally resource-rich land that possesses abundant water supply, naturally fertile soils, and a favourable terrain and climate.

Ultisols are acidic red soils that are always found in warm, temperate, humid climates and regions occupied with deciduous forests (Yu *et al.,* 2016). These special soil landscapes are majorly spread across tropical and subtropical areas. They are mainly found in some southern states of Nigeria such as Edo state and cover approximately seven zones which include central Benin and the extreme north (Dayou *et al*., 2017).Ultisols have naturally poor physical characteristics as they also possess low pH, cation exchange capacity, and fertility.Ultisols also have low concentrations of Phosphorus (P) which results in frequent Phosphorus deficiency of plants (Wang *et al.,* 2014). They are usually poor growing soils with low water holding capacity and can lead to anti-plant growth properties such as stunted growth and low plant yield. All these constitute a major developmental constraint to crop production and food security. This study therefore examines the quality of soil in the study area to understand its implication on agricultural and provide necessary recommendations for profitable agricultural management. Previous studies conducted on utisols that have been reported include Mbagwu (1992), Rongzhong et al. (2019), Onweremadu (2007), Ngwu et al. (2007), and Obi (1999). Worthy of note is that significant studies are yet to be conducted on degraded Ultisols in the humid areas of southern Nigeria, particularly in the study area. Similarly, the weathering potentials of utisols in the study area are yet to be examined. Following the stated aim of this study, specific objectives were set to determine the different characteristics of the soil, suggest alternative land use(s), and advise farmers on the best management options of the study area.

2.0 METHODS

2.1 Study area

This study was carried out on the Faculty of Agriculture farm (AGRIC 305 farm) (Figure 1), University of Benin main campus, Ugbowo, Benin City, Edo state Nigeria. It is located within latitudes 06° 24' 01.9" N and longitudes 05° 37' 32.9" E. (Ikhile, 2016). The study area is plain; gently sloped from west to east with moderate erosion activities and occupies five (5) hectares of land. Field observation shows that the area was previously used for arable crop cultivation. However, as at the time of observation, the area is fallowed with overgrown weeds and creeping legumes such as *Pueraria phaseoloides* and *Centrosemepubescens.*

2.2 Data collection

Data for this study such as soil depths regarding the nature of the vegetation and land-use types; the physical characteristics of the soil were primarily sourced through direct field observation. The soil Physico-chemical characteristics were obtained from the laboratory analyses of soil samples taken from different depths of a single profile of 15m apart (sampling points) and at two depths of 0-15cm (topsoil) and 15-30cm (subsoil).

A reconnaissance field survey was conducted to get familiar with the study area and identify potential challenges to be encountered. Existing environmental information on the study area was also sought from various literatures.

2.3 Fieldwork and soil sampling

The available soil survey report compiled by Okonsebor (2014) was obtained from the Soil science and Land Management Department. Soil details of the study area Pedon were correlated with the Ultisol and georeferenced using a hand-held Global Positioning System (GPS) and then dug. Various soil horizons of the pedon were identified and their boundaries marked. Morphological characteristics and field observation were carried out according to FAO (2000) guidelines. A total of five samples soils were collected from different horizons of the soil identified in the profile, from the top to the bottom into a well-labeled polyethylene. The soil samples were then taken to the laboratory for analysis.

2.4 Laboratory analysis

Soil Samples gotten from the genetic horizons of the pedon were air-dried,

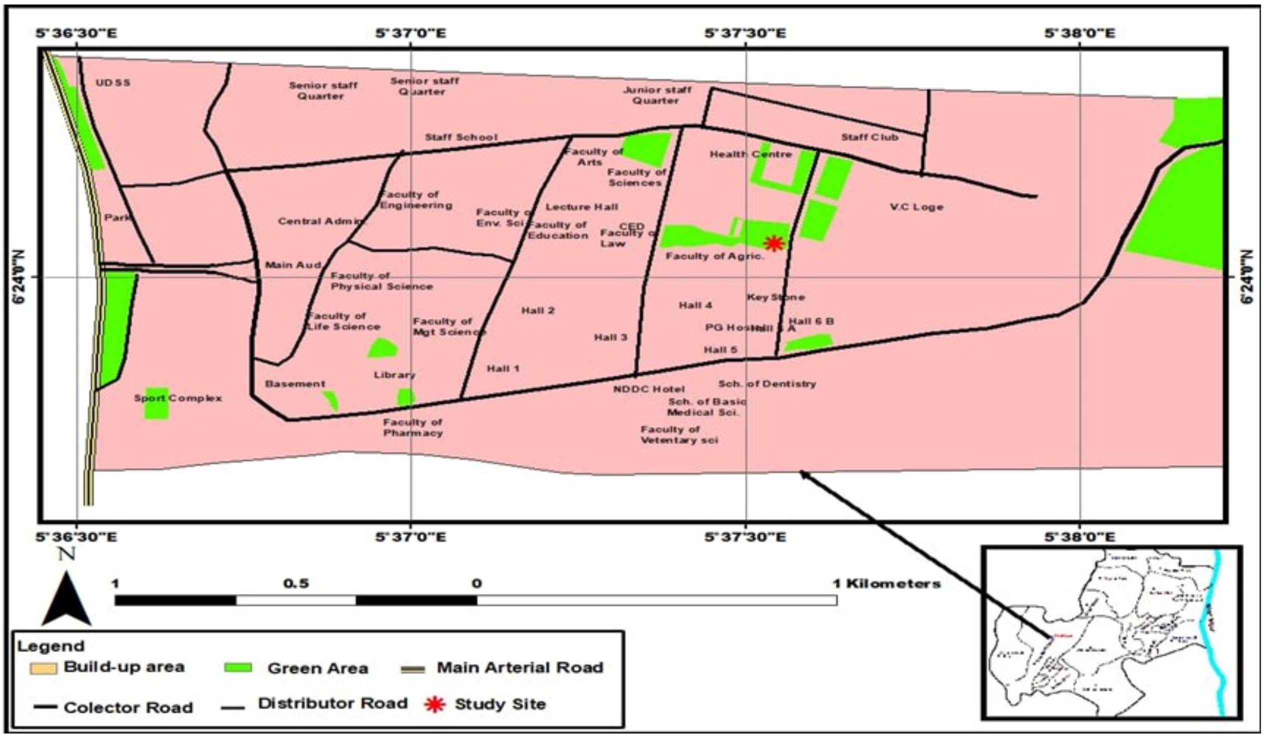

Figure 1: Map of University of Benin showing Faculty of Agric farm (Source: Google Earth Imagery modified by Author, 2021)

crushed, and sieved through a 2-mm sieve for laboratory analysis. Particle size analysis was determined by hydrometer method using sodium hexametaphosphate ($Na_6P_6O_{18}$) as dispersing agent (Okalebo *et al*, 2002) while bulk density was determined by collecting undisturbed core samples from each horizon using a core sampler ($216cm^3$).

2.5 Soil chemical analysis

Soil pH was determined in a 1:1 soil suspension ratio in water. The pH meter was calibrated using a pH 7 buffer solution. The meter was adjusted with the known pH of buffer solutions 4.0 and 9.2. Soil weighing 20g was transferred into a 100ml beaker. 40ml distilled water was added and stirred well with a glass rod. This was allowed to stand for half an hour with intermittent stirring. The glass electrode was immersed into the soil water suspension in the beaker and the pH value was determined and recorded from the automatic display of the pH meter.

Total Nitrogen (TN) was determined by Marco Kjeldahl digestion method. Exchangeable acids of Hydrogen (H^+) and Aluminum (Al^{3+}) were determined in KC1 extract by titration.

In determining Effective Cation Exchangeable Capacity (ECEC), the exchangeable acidity and the total exchangeable bases already determined were added. i.e.

ECEC = exchangeable acidity + total exchangeable bases.

Exchangeable bases such as Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na) were extracted within ammonium acetate (NH_4OA_C) buffered at pH 7; K and Na were read on a flame photometer and Ca and Mg by Atomic Absorption Spectrometer. The exchangeable base and acid were summed to determine the Effective Cation Exchange Capacity (ECEC) (Anderson and Ingram, 1993). The Percentage of Base Saturation (BS%) was calculated using equation (I).

Percentage of Base Saturation =

$$\left[\frac{Ca+Mg+K+Na}{ECEC}\right] \times 100 \quad \ldots\ldots\ldots\ldots \text{(I)}$$

2.6 Soil physical analysis

2.6.1 Bulk Density

The Bulk Density (BD) as expressed in equation (II) was determined by the Coring method (Abu-Hamdeh, 1999). This was done by oven drying the collected undisturbed core samples to a constant weight at 105 ^{0}C and dividing the oven-dried weight by the volume of the core sampler.

BD = $\frac{\text{WEIGHT OF OVEN-DRY SOIL}}{\text{VOLUME OF CORE}}$ ………….. (II)

2.6.2 Particle size

Particle size was determined by the method as described by Gee and Or (2002). The percentage sand, silt, and clay were determined using the Bouyoucous hydrometer which allowed the sedimentation at various intervals. Sodium hexametaphosphate was applied as the dispersant.

2.6.3 Total porosity

Total porosity was derived from the relationship of the particle to bulk density using the formula as expressed in equation (III)

Percentage pore space =

$$\left[\frac{1-BD}{PD}\right] \times 100 \quad \text{…………….. (III)}$$

Where; BD is the bulk density, and PD is the particle density.

The average particle density of 2.65Mg m^{-3} for mineral soils was used for computation.

2.7 Statistical analysis

The descriptive and inductive statistical methods were applied in this study. Primary Data collected from the laboratory was subjected to statistical analysis using the SPSS 16.0 version. Pearson's Correlation coefficient statistical test was used to measure the statistical relationships between soil variables. A significant relationship was observed at 0.05 (2-tiled) level and 0.01 (2-tiled) level.

4.0 Results and discussion

Results from the fieldwork are presented in this section. Tables and graphs were used in presenting the analysis. The chemical properties and physical characteristics of the soil sample from the study area are discussed below.

Morphological properties of the soil

The soil occurs over unconsolidated sandstone, moderately leached, non-stony, deep (>145cm), and located on the upper slope (8%) in the toposequence. Figure 2 shows the variety of colours and related soil properties.

Figure 2: Profile showing different horizons (Source: Authors Field Work, 2021)

Table 1: Morphological characteristics of the soil

Profile No.	Location	Horizon	Depth (cm)	Colour (moist)	Structure	Consistency (moist)	Texture	Bounda-ry	Root	Mottles
FARM 305	$06^0$24'01.9" N	A_p	0-18	5YR, 3/3(dark reddish brown)	1, f	l	SL	s,d	c, m	-
(Upper slope	$005^0$37'32.9" E	A_B	18-42	5YR, 3/3(dark reddish brown)	f, cr	fr	LS	w,d	c, fe	-
8%)		B	42-66	5YR, 4/4 (reddish brown)	2, m,sbk	fr	SL	w,d	f,	fe, f
		B_{t1}	66-89	2.5YR, 2.5/3 (dark red)	2, m, sbk	fr	SL	w,g	f	c, m
		B_{t2}	89-145	10YR, ¾(dark yellowish brown)	2, m, sbk	f	SL	-	n	-

Source: Author's Fieldwork
Key : Structure – 1 = weak, 2=moderate, m=medium, cr= crumb, f = fine, sbk = sub angular blocky
Consistency - L= Loose, f=fine, fr = friable
Texture - LS = Loamy Sand, SL= Sandy Loam
Boundary - s= smooth, d= diffuse, w= wavy, g = gradual
Root - c = coarse, f=fine, fe= few, m= many, n= none

From Table 1, it can be observed that the soils are weak, fine over a medium subangular blocky structure with dark reddish-brown colour (5YR 3/3, moist) in the first 42cm depth to dark yellowish-brown (10YR 3/4, moist) in the subsoil. The hue is a mixture of 2.5YR, 5YR to 10YR stipulating the dominant spectral colour of the soils of the area.

It can also be noted that the soil consistency (moist) ranges from loose at the topsoil to fine at the subsoil specifying a weak cohesion of the soil. A close observation of the field texture shows that it is almost sandy loam. Most of the horizon boundaries are wavy, while the top horizon has many coarse roots. As it may be expected, there are few to no roots at the subsoils which are due to a preponderance of grasses and few shrubs in the study area. There were little or no fauna activities in the soil profile but there was evidence of mottles in the endopedon. This is evidence of the redox condition of the soil as has been observed by Ugwa *et al*. (2016).

Table 2: Physical characteristics of the soil

PROFILE	Horizon	Depth (cm)	Colour (moist)	Silt (gkg^{-1})	Clay ($g\ kg^{-1}$)	Sand ($g,\ kg^{-1}$)	Silt/ Silt + Clay Ratio	Clay Activities	Texture	BulkDensity ($mg\ m^{-3}$)	Total Porosity (%)
FARM 305	A_p	0-18	5YR, 3/3	70	250	680	0.22	6.56	SL	1.56	41
	A_B	18-42	5YR, 3/3	50	150	800	0.25	10.33	LS	1.38	48
	B_1	42-66	5YR, 4/4	80	260	660	0.24	4.96	SL	1.28	52
	B_2	66-89	2.5YR, 2.5/3	200	200	600	0.50	6.66	SL	1.42	46
	B_t	89-145	10YR, 3/4	100	250	650	0.29	5.64	SL	1.42	46
		Mean		100	222	678		6.84		1.41	46.6

Key: LS= Loamy sand, SL= Sandy loam

Physical properties of the soil

Table 2 shows the physical characteristics of the soil as observed. It can be observed that the distribution of the soil fraction ranges between 600-800 g kg^{-1} with a mean distribution of 678 g kg^{-1}. The distribution of sand in the profile shows no pattern and seems to be similar to the work of Okunsebor (2014) who worked on similar soil. The same pattern follows the clay fraction that the A_p and B_t had 250 g kg^{-1} each to the clay. In the endopedon, it fluctuates between 150-260 g kg^{-1}. This fluctuation in the clay fractions may be due to the erosional circle in the upper slope of the area in which the profile is situated.

Generally, the silt content of the soil increased from the topsoil (70 g kg^{-1}) to the subsoil (200 g kg^{-1}) influencing the texture of the soil to be sandy loam. Soong and Lau (1977) had indicated that based on the different combinations of clay, sand and silt, soil texture is grouped into various textural classes. The bulk density values indicate that the soil was compact as they were generally high and ranged from 1.28-1.56m gm^{-3} with the lower value occurring at the topsoils and increasing gradually with soil depth. This might be due to a decrease in soil organic matter content and compaction due to the upper soil layers (Brady, 2002). The porosity value was also high (41-52%) as it seems to have an inverse relationship with the soil bulk density.

Evaluation of the soil development stages.

The stages of soil development and age have been estimated in the past using some weathering ratios. Ajiboye, Ogunwale, and Adeloju (2015) reported that silt/ silt + clay ratio of 0.7 indicates moderate weathering, <0.7 for severe weathering, and >0.7 for incipient weathering. Table 4.2 also shows that the value generally increases with soil depth. The highest value was recorded at 66 to 89 cm soil depth and the observed pattern may be due to the absence of clay illuviation in the soil profile. All the values show that they were less than 0.7. Therefore, the soils in that area are prone to severe weathering, giving credence to the report of clay activities. It seems that the silt/ silt + clay ratio of these soils presented a better picture of weathering stage of the soil development. Such practices as soil organic matter management and regular soil tests and planting of leguminous creeping crops are necessary for the management of the soils.

Chemical properties of the soil.

Detailed chemical properties of the soil sample from the study area are presented in Table 3.

Table 3: Chemical characteristics of the soil

Horizon	Depth (cm)	pH (H_2O)	OC	TN	Avail.P (mg kg^{-1})	EA	Ca	Mg	K	Na	ECEC	BS (%)	Mn	Fe	Cu	Zn
			g kg^{-1}			Cmol kg^{-1}							mg kg^{-1}			
A_{p1}	0-18	5.70	12.80	1.60	2.94	0.20	1.00	0.24	0.13	0.07	1.64	87.80	2.42	59.2	1.00	11.20
A_B	18-42	5.20	16.80	1.40	3.58	0.18	0.96	0.23	0.12	0.06	1.55	88.39	2.25	96.3	0.95	10.76
B_1	42-66	5.20	2.80	0.30	0.64	0.15	0,80	0.19	0.10	0.05	1.29	88.37	2.18	148.0	0.92	10.22
B_2	66-89	5.20	22.80	1.50	5.10	0.20	0.80	0.19	0.09	0.05	1.33	84.96	2.29	212.4	0.89	10.90
B_t	89-145	5.30	18.80	1.30	3.45	0.14	0.90	0.21	0.10	0.06	1.41	90.00	2.58	218.5	1.10	11.98
	Mean	5.32	14.80	1.22	3.14	0.17	0.89	0.21	0.11	0.06	1.44	87.90	2.34	146.88	0.97	11.01

Key:
OC - Organic Carbon; TN- Total Nitrogen; BS- Base Saturation
ECEC- Effective Cation Exchange Capacity
Ca- Calcium Mg- Magnesium Fe- Iron; Na- Sodium; K- Potassium; P- Phosphorous
Mn- Manganese; Zn- Zinc; Cu-Copper

From Table 3, the result shows that the pH of the soil ranges from 5.7 (topsoil) to 5.3 (subsoils). Generally, the soil is acidic in all the depths which might be due to the sandstone of the parent materials. According to Esekhade *et al*, (2003), tree crops in Nigeria thrive better in soil with such a range of pH, therefore the acidic nature of the soil may not pose any danger to crop production.

The Organic Carbon (OC) gives an estimate of the organic matter in the mineral soil (Buol *et al*, 1973). Its values range from 2.8-18.8g kg^{-1} with a mean value of 14.8 g kg^{-1}. This value is considerable when compared with the threshold value of 10-15 g kg^{-1} (moderate) for productive soils (Adiukwu and Ali, 2013). A good relationship between organic carbon and Total Nitrogen has been established by Brady (2002). They are reciprocal and ranged from 0.3 -1.6 g kg^{-1}. The moderate value of total nitrogen might have been due to the leguminous ground cover or perhaps, the previous intercropping in the study area. This has also been observed by Esekhade *et al.* (2003) and Ugwa *et al.* (2017). Phosphorus which is one of the macronutrients required in large amounts for crop growth is also considered low in all the soil horizons when compared with the critical value (15mg kg $^{-1}$) as presented by Adiukwu and Ali (2013) as its mean value in the study area is 3.14mg kg^{-1}.

The soil's Effective Cation Exchange Capacity (ECEC) ranges between 1.29-1.64 Cmol kg^{-1}. It decreases in value along with the soil profile following the pattern of the organic matter. This offers the contribution of organic matter to ECEC in the soils of the study area. The values of ECEC are lower than that reported by Kamalu *et al*. (2018). The low ECEC according to Kamalu *et al*. (2018) is attributed to the kaolinitic nature of the clay minerals having cations in the coastal region of southern Nigeria.

The values of the exchangeable cations (Ca, Mg, K and Na) are also presented in Table 3. They cannot be said to be high in value but are influenced by the soil parent materials and organic matter. It might also be due to the high rate of rainfall prevalent in the study area thereby subjecting the soil to excessive leaching. The Base Saturation (BS) found in the sample soil from the study area is higher than 80% and according to Adiukwu and Ali (2013), it is rated very high. This value corresponds with the values in the works of Esekhade *et al.* (2003), Ugwa *et al.* (2016), and Oko-Eboh *et al.* (2018).

Apart from Iron (Fe) which shows the highest amount in the study site soils, the other available micronutrients seem to be low.

They ranged in value as Fe>Zn>Mn>Cu. The critical value of the available micronutrient according to Amhakhian and Osenwota (2012) are Fe (5.0mg kg^{-1}), Mn (2.5mg kg^{-1}),Cu (2.0-3.0 mg kg^{-1}) and Zn (0.8 mg kg^{-1}). Zn is said to be high in the soils and may be prone to toxicity in the soil. Micronutrient deficiencies are attributed to the nutrient imbalance by heavy depletion of basic cation and phosphorus in the soil complex (Mpanda *et al.,* 2016).

Correlation matrix of the soil proportion

Table 4 shows the correlation matrix of the soil proportion in the study area. The matrix reveals that six soil properties were positively significant while two were negatively significant.

The positively correlated properties are silt with clay ($p<0.01$), bulk density with pH ($p<0.05$, organic carbon with available P ($p<0.01$), Mn with Cu ($p<0.05$), Mn with Zn ($p<0.01$) and Cu with Zn ($p<0.05$).

The highly significant relationship between silt and clay suggests that at the topsoil the more there is silt, the more the clay would be in the soil complex. As the acid nature of the soil decreases, the more the value of the bulk density would increase. It signifies that the organic matter may not have been sufficient in the topsoils. Furthermore, low organic matter in the soil has a negative value on available phosphorus and according to Brady (2002), an increase in the organic matter content of the soil improves the readily available content of the phosphorus status of the mineral soil. Apart from Fe, there is a preponderance of Mn than Cu and Zn. These are micronutrients. The significant positive relationships observed in these micronutrients that are essential for crop function indicate that they are complementary.

Table 4 also shows the significant negative relationship that is between bulk density with total N ($p<0.01$) and between total N with pH ($p<0.05$). The significance of this is that the more the soil of the study site becomes alkaline, the more organic matter is been made available and may lower the bulk density value. Compact soils have a negative influence on root development. Generally, soil tests in the study area and crop residue management may be essential in the management of these fragile Ultisols.

Table 4: Correlation matrix of the soil properties

Sand	Silt	Clay	BD	TN	pH	OC	Avail P	EA	ECEC	BS	Mn	Fe	Cu	Zn
1														
-0.613	1													
-0.613	1.000**	1												
-0.070	0.079	0.079	1											
0.107	-0.076	-0.076	-0.998**	1										
-0.028	0.416	0.416	0.857*	-0.830*	1									
-0.124	-0.507	-0.507	0.431	-0.479	-0.091	1								
-0.132	-0.554	-0.554	0.469	-0.511	-0.050	0.980**	1							
0.017	-0.411	-0.411	0.602	-0.590	0.396	0.376	0.543	1						
0.590	-0.234	-0.234	0.752	-0.719	0.737	0.138	0.166	0.461	1					
0.406	0.301	0.301	-0.134	0.147	0.099	-0.350	-0.510	-0.773	0.206	1				
-0.229	0.355	0.355	0.587	-0.617	0.449	0.444	0.314	-0.231	0.303	0.450	1			
-0.647	0.137	0.137	-0.369	0.308	-0.603	0.408	0.316	-0.427	-0.786	-0.112	0.254	1		
0.046	0.377	0.377	0.365	-0.379	0.376	0.152	-0.012	-0.505	0.332	0.780	0.910*	0.104	1	
-0.179	0.190	0.190	0.565	-0.602	0.340	0.588	0.458	-0.186	0.292	0.388	0.982**	0.316	0.869*	1

Note: * = correlation is significant at the 0.05 level (1-tailed), ** = correlation is significant at the 0.01 level (1-tailed)

Conclusion

This paper successfully evaluated the morphology and physio-chemical properties of degraded utisols to determine their agricultural potential. Results revealed that the soil in the study area is severely weathered with attendant erosion activities. Evaluation of the chemical properties of the soil revealed that it is acidic in all the depths profile with a moderate value of total nitrogen. However, phosphorus, which is a macronutrient required in large amounts for crop growth and development was considerably low as it decreased in value along with the soil profile and the pattern of organic matter. Statistical analysis revealed that the soil pH concentrations in the topsoil and subsoil were not significantly different as they were within moderate range for establishing tree crops like oil palm and rubber. The soil, therefore, needs to be improved to enhance its productivity and harness its full potential to support food production. Erosion control measures should be the fundamental step towards achieving an improved soil quality in the study area because of the amount of precipitation observed. Planting cover crops and tree crops, such as rubber and cocoa are also recommended because of the deep nature of the soil and the sloping nature of the area. The study, therefore, recommends regular appraisal of the fertility of the soil within the study area for maximum agriculture yield

REFERENCES

Abu-Hamdeh N. H., Al-Jalil H. F. (1999): Hydrau-lically powered soil core sampler and its application to soil density and porosity estimation. *Soil Tillage Res.,* 52: 113–120.

Adaikwu A. O and Ali A. (2013). Assessment of Some Soil Quality Indicators in Benue State. *Nigeria Journal of Soil Science,* 23(2), 66-77.

Ajiboye G. A., Ogunwale J. A. and Adeloju M.O. (2015). Profile Distribution of Crystalline and Amorphous Sesquioxides in Take Over burnedSoils of Southern Guinea Savanna Ecology in Nigeria. *Nigeria Journal of Soil Science.* 25, 58-69.

Amhakhian S. O and Osemwota I. O. (2012). Physical and Chemical Properties of Soil in Kogi State, Guinea Savanna Zone of Nigeria. *Nigeria Journal of Soil Science Society of Nigeria Conference, Ibadan*, 22, (1), 37-43

Anderson J. M. and Ingram J. S. I. (1993). Tropical Soil Biology and Soil Fertility: A Handbook of Methods. Wallingford, UK: C.A. B International.

Azad-Hossain A.K.M. (2013). Humid Tropics: Vulnerability of Water Resources to Climate. Retrieved from https://www.sciencedirect.com/topics/agriculture-and-biological-sciences/humid-tropics.

Brady N. C. (2002). The nature and properties of soils. 1oth Ed. Prentice-Hall of India Private Ltd., New Delhi, India.

Buol S.W., Hole F.D and McCracken R. J. (1973). Soil Genesis and classification. 1st Ed. Iowa: The State University Press.

Dayou E.D.,Zokpodo K.L.B. and Glèlè K.L.R. (2017). Assessment of the Physical and Mechanical Properties of the Soils in the Different Agroecological Zones of Benin. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension,* 16(3), 37-45

Food and Agriculture Organizations of the United Nation (FAO) (2000). A Provisional methodology for soil degradation assessment. In: A world agriculture Towards 2020. An FAO study. A Nikos (ed). London; Belhaven Press.

Food and Agriculture Organizations of the United Nation (FAO) (2015). Soil is a non-renewable resource. Accessed via https://www.fao.org/soils-2015/en/

Gee G.W. and Or D. (2002). Particle Size Analysis. In: Dane, J.H. and Topp, G.C., Eds., Methods of Soil Analysis. Part 4, Physical Methods, SSSA, Incorporated, Madison, 255-294.

Ikhile, C. (2016) Geomorphology and Hydrology of the Benin Region, Edo State, Nigeria. *International Journal of Geosciences*, **7**, 144-157.

Kamalu O. J., Ugwa, I. K. and Omenihu, A. A. (2014). Survey, Classification and Suitability of Akwete soils for rubber *(Heveabrasiliensis)* cultivation in Southern Nigeria. *ACTA Agronomica Nigeria*, 14, 56-63.

Mbagwu J.S.C. (1992). Improving the productivity of a degraded ultisol in Nigeria using organic and inorganic amendments. *Bioresource Technology*, 42(3), 167-175.

Mpanda, Mathew & Majule, Amos & Marchant, Rob & Sinclair, Fergus. (2016). Variability of Soil Micronutrients Concentration along the Slopes of Mount Kilimanjaro, Tanzania. *Applied and Environmental Soil Science.* 2016. 1-7. 10.1155/2016/9814316.

Ngwu O. E., Mbagwu J. S., and Obi M. E. (2007). Productivity of Degraded Ultisol in South-Eastern Nigeria Using Desurfacing Technique (DT) for Sustainable Agriculture. *International Journal of Agriculture and Development.* 9, 123-127

Onweremadu E.U. (2007). Characterization of a Degraded Ultisol Amended with Cassava Peel, Cattle Dung and Poultry Droppings in Southeastern Nigeria. *Journal of Plant Sciences*, 2, 564-569

Okalebo S.R., Guthua K.W. and WoomerP.L. (2002). Laboratory methods of soil and plant analysis; A Working manual. 2nded. TSBF-CIAT and Sacred Africa, Nairobi; Kenya, pp 128

Oko-Eboh E., Ugwa I. K., Eruaga A. M. and Aboh S. I. (2018). Evaluation of Potentials and Management constraints of Indaloke Series for Coconut (Cocus nucifera) Production in rainforest ecology of Southern Nigeria. *International Journal of Agriculture and Rural Development*, 21(1), 3414-3424.

Oko-Oboh E. (2014). Comparative Assessment of different land evaluation approaches for oil palm cultivation in soils of Ohosu, Edo State. Unpublished Ph.D Thesis, Federal University of Agriculture, Abeokuta, Nigeria.

Okunsebor F. E. (2014). Soil Mapping and Classification of a 62-hectare parcel of land at the University of Benin Teaching Research and Integrated Farm Site. Unpublished M.Sc. Project, University of Benin, Benin City.

Omorogiuwa O., Zivkovic J. and Ademoh F. (2014). The Role of Agriculture in the Economic Development of Nigeria. *European Scientific Journal, Nigeria,* 10 (4),1857-7881.

Obi M.E. (1999). The physical and chemical responses of a degraded sandy clay loam soil to cover crops in southern Nigeria. *Plant and Soil*. 211(2), 165-172

Rongzhong Y., Binaya P., and Gilbert S. (2019). Subsurface Clay Soil Application Improved Aggregate Stability, Nitrogen Availability, and Organic Carbon Preservation in Degraded Ultisols with Cover Crop Mixtures. *Soil Biology & Biochemistry.*83(3), 597-604.

Soong N. K. and Lau C. H. (1977). Physical and chemical properties of soil. In: Soil under Heavea and their management (ed) E. Pushparajah and L. I., Amin. in Peninsula Malaysia. Rubber Research Institute of Malaysia, Kuala Lumpur.

Soil Science Society of America (2021). Soil formation.Obtained from https://www.soils4teachers.org/formation/

Ugwa I. K., Umweni A.S. and Bakare A. O., (2016). Properties and agricultural potentials of Kulfo series for Rubber cultivation in humid lowland area of southern Nigeria. *International Journal of Agriculture and Rural Development*, 19(2), 2788-2795

Wang Y.L., Tang J.W., Zhang H.L., Schroderm J.L. and He Y.Q.(2014). Phosphorus availability and sorption as affected by long-term fertilization. *Agronomy Journal*, 106,1584-1592.

Yu H., Li B., Liu S., Huang W., Liu T. and Yu W. (2016).Iron redox cycling coupled to transformation and immobilization of heavy metals: Implications for paddy rice safety in the red soil of south China. *Advances in Agronomy,* 137, 65-73.