Direct Research Journal of Agriculture and Food Science
Vol. 11(6), Pp.153-161, June 2023
ISSN 2354-4147
DOI: https://doi.org/10.26765/DRJAFS3739055
Article Number DRJAFS3739055

https://directresearchpublisher.org/drjafs/

Original Research

Soils and Its Degradation Status in Ochobo, Ohimini Area of Benue State, North Central Nigeria

***Igomu, E. A.[1], Igomu, B. C.[2] and Osujieke, D. N.[3]**

[1]Department of Soil Science, Joseph Sarwuan Tarka University Makurdi, Nigeria.
[2]Department of Science Laboratory Technology, Benue State Polytechnic Ugbokolo, Benue State, Nigeria.
[3]Department of Soil Science and Land Resources Management, Federal University, Wukari, Taraba State, Nigeria.
Corresponding Author E-mail: igomumajor@gmail.com

Received 2 June 2023; Accepted 26 June 2023; Published 28 June 2023

ABSTRACT: Soil characterization studies are an important building block to understand soil, classify it and get the best understanding of the environment. The extent of soil degradation in Nigeria for effective environmental management has been most felt in recent times as the trend of environmental degradation is increasing, which necessitated an assessment. The assessment took into consideration the characteristics of vegetation degradation and soil contamination that lead to soil degradation. In 2020, the assessment was carried out in Ohimini area of Benue State. The conventional method was used to assess the degree of soil degradation in the study area. The physical and chemical properties of the soils were examined in the laboratory and the results were compared with the standard indicators and criteria for assessing soil degradation. The laboratory results showed that most of the eroded parts of the study areas were highly degraded compared to the soils under vegetative growth. Considering the study results, the studied soils differed significantly in their physico-chemical properties, highlighting the need to characterize the soils before initiating soil fertility management strategies and practices for improved sustainable agricultural production. The widespread removal of natural vegetation as a result of human activities such as farming, logging and mining which encouraged fertility erosion was identified as the main type of degradation in the areas. Restoration efforts should be directed to areas of severely degraded land and also to areas that are not at high risk to lessen the overall effect of degradation in the area.

Keywords: Soil degradation, physical, chemical, Benue, status, Ohimini

Citation: Igomu, E. A., Igomu, B. C. and Osujieke, D. N. (2023). Soils and Its Degradation Status in Ochobo, Ohimini Area of Benue State, North Central Nigeria. Direct Res. J. Agric. Food Sci Vol. 11(6), Pp. 153-161. https://doi.org/10.26765/DRJAFS3739055

INTRODUCTION

Soil is a vital natural resource which plays an important role in plant growth and development for the livelihood of mankind. Pedological characterization as a systematic way of gathering soil information provides a clear understanding of soils in terms of their morphological, physical, chemical, biological and mineralogical properties; hence their potential and limitations for crop production (Msanya *et al.,* 2016; John *et al.,* 2018). The process of developing a soil map forces one to understand the fundamentals of soils, how they were formed, occur across the landscape or the globe, and how they might respond to use and management. According to Hartemink (2012), soil mapping also aims to uncover gaps in our understanding of soil properties and processes over time and place. Land degradation is caused by both natural and anthropogenic phenomena, where the former cannot be changed, and the latter can be mitigated (Vu *et al.*, 2014). Land degradation also refers to a temporary or permanent decline in the productive capacity of the land. Land degradation can be viewed as any change or disturbance to the land perceived to be deleterious or undesirable (Eswaran, *et al*., 2001). Land is being degraded because of inappropriate use. Under intensive agriculture and grazing, surface horizons are subjected to the compaction effect of machineries and animals which exert pressure on the land, thereby adversely affecting water and air movement, seedling emergence and root penetration.

Land degradation also occurs as a result of climatic and human factors. The increase in nomadic lifestyle has transformed traditional, ecologically balanced, pastoral systems to potentially unsustainable sedentary agriculture. This transformation has increased human and animal pressures on the fragile resource base and ecosystems of the environment, creating a cycle of resource degradation and human poverty, threatening biodiversity, and accelerating environmental deterioration (Abdel-Kader, 2014).

Erosion of soil by wind and water is both a human and natural phenomenon. Also, the use of forest and grassland by man for agriculture has changed the equilibrium between the rates of soil formation and erosion that occur in nature. While climate and topography make bare soil vulnerable, tillage and intensive grazing, urban sprawl, high population densities, indiscriminate forest clearing and burning have contributed to change in the landscape due to erosion.

Many technologies and approaches used in food production systems have exploited the natural resources and degraded the environment. There are practically no extensive areas of land without limitation of one sort or another. Natural hazards are excluded as a cause of land degradation; however, human activities can indirectly affect phenomena such as floods and bush fires. The major causes of land degradation include; land clearance, poor farming practices, overgrazing, inappropriate irrigation, urban sprawl, and commercial development, land pollution including industrial waste and quarrying of stone, sand and minerals. Sustainability of agriculture therefore requires that such problems have to be definitely arrested (Aydinalp, 1996).

The objectives of this work were to identify major factors responsible for degradation, using sample areas, and establish the degree of degradation of the soils of Ohimini area using standard indicators and criteria for land degradation assessment.

MATERIALS AND METHODS

Study area

The study was carried out in Ohimini (Ochobo) Local Government Area located in the Southern part of Benue State, North Central Nigeria, approximately within latitudes $7^0 07' 45''$ N and $7^0 14' 33''$ N and longitudes $7^0 31' 42''$E and $7^0 55' 42''$E.

Climate

Ohimini Local Government Area falls within the humid tropics. There are two major seasons in the year- the rainy season and the dry season. These correspond to the prevalence of the moisture-laden south-westerly maritime wind that originates from the Atlantic Ocean and the dry continental north-easterly wind from the Sahara desert, respectively.

Rainfall (mean annual) is about 1600 mm falling within 7 to 8 months of the year, while the remaining 4 to 5 months are dry. The mean annual temperature range is between 21 ^{0}C and 31 ^{0}C. The relative humidity is dependent on the seasons. It ranges from 45 % during the dry season months of December to February to 75 % during the rainy season months of May to September.

Vegetation

The vegetation was originally that of tropical rainforest, now turned savanna due to anthropogenic activities, with relic of scattered secondary forest regrowth dotting the landscape. The major tree species of the area include oil palm tree (*Elaeis guineensis),* African mahogany *(Kaya ivorensis),* mango (*Mangifera indica*), iroko tree (*Milicia excelsa*), neem tree (*Azadirchata indica*) teak (*Tectona grandis*) and African locust bean (*Parkia biglobosa)*. The major grasses of the derived savanna include; beard grass (*Andropogon gayanus),* thatching grass (*Hyperrhenia spp)*.

Agriculture and present land use

Subsistence agriculture is the major land use, producing less than enough to feed the family. The major crops are cassava (*Manihot spp*), groundnut (*Arachis hypogea*), cowpea (*Vigna unguiculata*), maize (*Zea mays*), yam (*Dioscorea spp*), and a variety of vegetables, such as okra (*Abelmoschus esculentus* L.) and amarantus (*Amarantus spp*).

Field Methods

Identification of sample areas and soil sampling

These areas represented the degraded sites alongside non degraded sites. In the sample areas, soil samples were randomly collected from four auger points (two from each area) with two depths as surface soil (0 – 15 cm) and subsurface (15 – 30 cm), and properly labelled.

Samples were labelled as degraded I and II, and non-degraded I and II for each location.

Laboratory Methods

Soil physical analysis

Particles size distribution: the Buoyoucos Hydrometer method as described by Bouyoucos in Van Reeuwijk (1992) was used.

Bulk density: the soil dry bulk density was determined using the core method.

Soil total porosity: the total porosity of the soil samples was determined from the relationship; $\%F_t = (1 - Bd/Pd) \times 100$
Where: F_t = total porosity, Bd = bulk density (g/cm^3), Pd = particles density of the soil = 2.65 g/cm^3

Saturated hydraulic conductivity: in this study, the constant head method was used to determine K_{sat}.

Soil chemical analysis

Soil pH: The soil pH in water (1:1) and in KCl (1:1) was determined by electrometric method (Thomas, 1996).

Organic carbon: organic carbon content of the soil samples was determined by the modified Walkley-Black method as described by Nelson and Summers (1996).

Total nitrogen: total nitrogen was determined by the Macro-Kjeldahl digestion and distillation procedures as described by Bremner (1996).

Cation exchange capacity (CEC): the CEC was determined by neutral, 1N ammonium acetate method.

Available phosphorus: sodium bicarbonate {Na $(HCO_3)_2$} extracting solution was used in this analysis (Olsen and Summers, 1982).

Exchangeable bases: this was determined using the 1N NH_4OAC (Hesse, 1971). Na and K were determined using the flame photometer while Ca and Mg were determined using Atomic Absorption Spectrometer (AAS).

Exchangeable acidity: the exchange acidity was determined using Barium Chloride Triethanolamine method as described by (Mclean, 1982).

Base saturation: this was calculated by dividing the sum of exchangeable bases by CEC and multiplying by 100.

$$BS(\%) = \frac{\text{Exchangeable bases}}{\text{Cation Exchange Capacity}} \times 100$$

Effective cation exchange capacity (ECEC): this was calculated by summing up the exchangeable bases plus the exchangeable acidity.

Exchangeable sodium percentage (ESP): this was calculated by dividing the exchangeable sodium by CEC and multiplying by 100.

Sodium adsorption ratio (SAR): this was calculated from the relationship:

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

Land degradation assessment

The degradation status of the soil in the various locations was assessed by field observation and the standard indicators and criteria for land degradation assessment by Food and Agriculture Organization (FAO, 1979). Table 1 shows these indicators and criteria. The four degrees of degradation identified include:

a. None to slightly degraded soil, where productivity ranged from 75 - 100 %
b. Moderately degraded soil, productivity ranged from 50 – 75 %
c. Highly degraded soil, productivity ranged from 25 – 50 %
d. Very highly degraded, productivity ranged from 0 – 25 %

Interpretation of results of analysis

The interpretation of the results of the laboratory evaluation of the soils were based on the guideline listed in (Table 2).

RESULTS AND DISCUSSIONS

Physical properties of soils of the study areas

The physical properties of the soils in the two (2) sites assessed are shown in (Table 3).

Soil texture

In Ochobo I, the percentages of soil particle sizes in both surface and sub surface soils varied between 65.36 and 54.36 for sand; 9.28 and 13.10 for silt; and 25.35 and 32.20 for clay in the degraded areas.

Table 1: Indicators and criteria for land degradation assessment.

Indicator	Degree of Degradation			
	1	2	3	4
Bulk density (gcm^{-3})	<1.5	1.5-2.5	2.5-5	>5
Permeability (cm.hr)	<1.25	1.25-5	5-10	>20
Content of Nitrogen Element (multiple Decrease) N (%)	>0.13	0.13-0.10	0.10-0.08	<0.08
Content of phosphorus Element ($cmo.kg^{-1}$)	>8	8-7	7-6	>6
K Content ($cmol/kg^{-1}$)	>0.16	0.16-0.14	0.14-0.12	<0.12
Content of ESP (increase by % of CEC)	<10	10-25	25-50	>50
Content of Base Saturation (decrease of saturation in more than 50 %)	<2.5	2.5-5	5-10	>10
Excess salts (salinization) (increase in conductivity Mmhos/cm/yr)	<2	2-3	3-5	>5
Content of humus in soil	>2.5	2.5-2	2-10	<1.0

Source: FAO (1979).

Key: Class 1: None to slightly degraded; Class 2: Moderately degraded; Class 3: Highly Degraded; Class 4 Very Highly Degraded

Table 2: Interpretation guide for evaluating analytical data.

(a) Exchangeable cations

Ca^{2+}	Mg^{2+}	K^{+}	Na^{+} (cmol/kg)	Class
<2	<0.3	<0.2	<0.1	Very low
2-5	0.3-1	0.2-0.3	0.1-0.2	low
5-10	1-3	0.3-0.6	0.3-0.7	Moderate
10-20	3-8	0.6-0.12	0.7-2	High
>20	>8	1.2-2	>2	Very high

(d.) Hydraulic conductivity (USDA SCS 1974)

Range (cm/hr)	Class
<0.13	Very low
0.13-0.51	low
0.51-2.0	Moderately low
2.0-6.3	Moderate
6.3-12.7	Moderately rapid
12.7-25.4	Rapid
>25.4	Very rapid

(b.) Cation Exchange Capacity (CEC)

Range (cmol/kg)	Class
<6	Very low
6-12	Low
12-25	Moderate
25-40	High
>40	Very high

(c.) Percentage base Saturation

Range (%)	Class
0-20	Very low
20-40	Low
40-60	Moderate
60-80	High
>80	Very high

(e.) Organic matter rating and interpretation Rating by Metson (1961)

Range (%)	Class
<2	Very low
2-4	Low
4-10	Medium
10-20	High
>20	Very high

(f.) Soil pH

Range	Rating
<4.5	extremely acid
4.5-5.0	Very Strongly acid
5.1-5.5	Strongly acid
5.6-6.0	Moderately acid
6.1-6.5	Slightly acid
6.6-7.5	Neutral
7.4-7.8	Slightly alkaline
7.9-8.4	Moderately alkaline
8.5-9.0	Strongly alkaline
>9.0	Very strongly alkaline

(g) Total nitrogen Rating by Metson (1961)

Range (%)	Class
<0.1	Very low
0.1-0.2	Low
0.2-0.5	Medium
0.5-1.0	High
>1.0	Very high

(h.) Organic carbon

Range (%)	Class
<0.4	Very low
0.4-1.0	Low
1.0—1.5	Moderate
1.5-2.0	High
>2.0	Very high

Available phosphorus Rating by Enwezor *et al.* (1989)

Bray 1		Bray 2	
Range (ppm)	Class	Range (ppm)	Class
<8	Low	15	Low
8-20	Medium	15-25	Medium
>20	High	>25	High

Source: Special Programme for food Security, Fed. Ministry of Agric. And Rural Devpt. (SPFS FMARD) FAO (2004).

For the non-degraded, values varied between 56.30 and 45.34 for sand; 13.29 and 14.19 for silt; and 30.36 and 40.47 for clay content. The soil textural class was clay loam for both surface and sub surface soils, except for sub surface soil of Site I non-degraded (15 – 30 cm), which was sandy clay. Soils of Ochobo II had percentages between 67.26 and 63.44 for sand; 11.27 and 12.08 for silt; and 21.45 and 24.46 for clay in the

Table 3: Physical properties of soils of the study areas.

Locations	Depth (cm)	Bulk Density (g/cm^3)	K_{Sat} (cm/hr)	Sand (%)	Silt (%)	Clay (%)	Silt/Clay ratio	Textural Class
Ochobo I Degraded	0-15	1.41	3.00	65.36	9.28	25.35	0.37	Clay loam
	15-30	1.49	2.20	54.36	13.10	32.20	0.41	Clay loam
Non-Degraded	0-15	1.28	3.90	56.30	13.29	30.36	0.44	Clay loam
	15-30	1.31	2.10	45.34	14.19	40.47	0.35	Sandy clay
Ochobo II Degraded	0-15	1.47	2.90	67.26	11.27	21.45	0.53	Sandy clay loam
	15-30	1.52	2.40	63.44	12.08	24.46	0.50	Sandy clay loam
Non-Degraded	0-15	1.20	3.50	60.10	13.40	26.50	0.51	Clay loam
	15-30	1.21	3.20	58.70	12.81	28.47	0.45	Clay loam

degraded area. Values for non-degraded ranged between 60.10 and 58.70 for sand; 13.40 and 12.81 for silt; and 26.50 and 28.47 for clay. The soil textural class for degraded was sandy clay loam and non-degraded area was clay loam. The subsoil silt/clay ratios of both soils (Ochobo I and II) were lower than those of the topsoil indicating that the subsoils are more weathered than the topsoils except for Ochobo I (degraded). The decrease of silt/clay ratio values with depth indicates that subsoils are more weathered than topsoils. Karuma *et al.* (2015) reported similar results for soils of Busia County in Kenya. According to Fitz-Patrick (1986), the textural class of the soil is a function of weathering in association with parent materials. The texture of soils has high influence on the physical and chemical properties of the soils; it is used as quality indicators for the land degradation assessment. The sandy nature of the soils, its low organic carbon content and CEC lead to low plant nutrients.

Soil bulk density

The soil bulk density (BD) values for Ochobo I ranged from 1.41 to 1.49 gcm^{-3} for the surface and subsurface soils in degraded area, and 1.28 to 1.31gcm^{-3} in non-degraded area. Values ranged between 1.47 to 1.52 gcm^{-3} in degraded area, and 1.20 to 1.21 gcm^{-3} in non-degraded area for Ochobo II. The degree of degradation of the soils with respect to bulk density ranged from slightly degraded to moderately degraded soils. The bulk density of the soil is greatly influenced by the organic matter and clay content. According to Uwitonze *et al.* (2016), high ability of retaining water related to high clay content enables soils to hold more water, thereby contributing to moisture reserve for plants during the dry period. Higher bulk density value was in the degraded sites, compared with the non-degraded sites, an indication of lower clay content and organic matter content in the degraded areas. The

Saturated hydraulic conductivity (K_{Sat})

The K_{Sat} for Ochobo I indicated moderate permeable for degraded and non-degraded areas having values between 3.00 and 2.20 cmhr^{-1}**,** and 3.90 and 2.10 cmhr^{-1}. Values ranged between 2.90 and 2.40 cmhr^{-1} in degraded area, and 3.50 and 3.20 cmhr^{-1} in non-degraded area of Ochobo II. Hydraulic conductivity depends on the intrinsic permeability of the materials and the degree of saturation. The K_{Sat} in the study areas indicated moderate to moderately rapid status. This may be attributed to the fact that some parts of the soils have substantial clay content and moderate water holding capacity. The K_{Sat} values decreased with depth, and can be attributed to the increase in clay content and bulk density with depth.

Chemical properties of soils of the study areas

The results of the chemical analysis of the soils in the two sites are presented in (Table 4).

Soil reaction (pH)

The average pH values for Ochobo degraded and non-degraded Sites, showed strongly acid (5.23 and 5.22) for degraded and moderately acid (5.12 and 5.94) for non-degraded Site. Landon (1991) reported that acidic soils with low pH (< 5.5) have a great potential to cause Al toxicity, deficiencies of some essential nutrients to plant growth and retardation of bacterial activity and decomposition of organic matter. The strongly acid condition as observed in the degraded parts of Ochobo I and II may be attributed to the loss of exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), through the effect of strong leaching as enhanced by high rainfall and soil porosity as, well as the sand fraction resulting from quartz mineral in the parent material (Barbar and Dupreez, 1965) and continuous removal of crop residues and burning during farming practices. Notwithstanding, the

Organic carbon

The average organic carbon values, the degraded and non-degraded areas in Ochobo I, were rated low with values of 1.17 and 1.59 %, while Ochobo II had low organic carbon (0.61 and 0.98 %) values in the degraded and non-degraded areas. The low organic carbon content

Table 4: Chemical properties of soils of the study area.

Locations	Depth (cm)	pH (H_2O)	pH KCl	OC (%)	TN (%)	Av. P (mg/kg)	K^+ /----	Ca^{2+} ------	Mg^{2+} -------	Na^+ (cmol	E.A /kg)	CEC ------	ECEC -----/	BS (%)	ESP (%)	SAR
Ochobo I Degraded	0-15	5.24	5.11	1.49	0.41	5.22	0.34	2.92	2.14	0.24	1.38	8.44	7.02	66.82	2.84	0.15
	15-30	5.22	5.13	0.84	0.04	5.00	0.28	2.78	2.29	0.21	1.34	7.34	6.90	75.75	2.86	0.13
Non degraded	0-15	5.17	5.02	1.81	0.72	6.34	0.31	3.55	2.85	0.20	1.54	10.88	8.48	63.79	1.84	0.09
	15-30	5.07	5.00	1.37	0.41	4.36	0.29	3.51	2.97	0.18	1.43	9.36	8.38	74.25	1.92	0.08
Ochobo II Degraded	0-15	5.12	4.67	0.64	0.06	3.30	0.24	2.50	2.44	0.22	1.00	9.91	6.40	54.49	2.22	0.20
	15-30	5.32	4.77	0.58	0.06	3.23	0.21	2.19	2.11	0.23	1.10	9.80	5.84	48.37	2.35	0.22
Non degraded	0-15	5.96	5.30	1.09	0.11	4.70	0.29	3.60	2.96	0.20	1.10	10.03	8.15	70.29	2.00	0.11
	15-30	5.92	5.01	0.86	0.09	5.20	0.27	3.44	2.98	0.20	1.00	10.00	7.89	68.90	2.00	0.11

non-degraded sites had higher pH values because of the minimal rate of leaching compared with the degraded sites.

in most of the sites was indicative of very high biological degradation of the study areas. The organic carbon depletion may be in part, due to soil erosion exacerbated by continuous cropping without adequate measures of nutrient replacement either through the use of inorganic fertilizer or other forms of soil conservation measure. Among the reasons advanced for low organic carbon content of the soils are vegetation cover, climate and other forms of human interference such as removal of plant materials for various uses (Agbim, 1991). Soil drainage appears to have strong influence on the organic carbon content. When the soil is poorly drained, there will be high accumulation of organic matter. Furthermore, the low OC contents of the soil may be accredited to rapid decomposition, as a resultof high temperature, good aeration, as well as the sandy nature of the soils (up to 80.0 % in some cases) (Adaikwu, 2010).

Total nitrogen

For Ochobo I, the average N values were 0.23 in the degraded and 0.57 in the non-degraded, while the Averaged values for degraded and non-degraded were 0.06 and 0.10 in Site II. The trend is an indication of nutrient loss in the areas due to continuous cultivation and erosion as well as nutrient loss during the harvesting period (Igomu and Idoga, 2017). Agbede (2009) listed nitrogen as the most important of all the 16 essential plant elements needed for plant growth, development and reproduction and also the most easily deficient throughout the world especially in the tropics. Nitrogen as a mobile element can easily be lost. TN shows a positive correlation with organic carbon, implying that organic matter was the major source of TN in the soils investigated. This is supported by the findings of Lawal *et al.* (2012) that organic matter accounts for between 90 and 98 % of soil nitrogen. The very low nitrogen status in all the soils might have been as a result of uptake by plant exacerbated by continuous cropping.

Available phosphorus

Ochobo I, values ranged from 5.00 to 5.22 mg/kg in the degraded and 4.36 to 6.34 mg/kg in non-degraded. Site II had values ranged from 3.23 to 3.30 for the degraded, and 4.70 to 5.20 in non-degraded. The Av. P was rated low in both degraded and non-degraded soils. It was observed that phosphorus content decreased with depth and appreciable quantities were found only at the top soils. However, the irregular pattern in accumulation of phosphorus at the surface; a pronounced occurrence in the savanna was attributed to decrease in the return of P to soil surface as the vegetation becomes sparser (Raji *et al.*, 1996). The low P might have resulted from the low pH (Onyekanne *et al.,* 2012). Phosphorous is the second most critical element influencing plant growth and crop production worldwide. It is taken up by plant from the soil solution in the form of phosphate.

Exchangeable cation

The Calcium values ranged from 2.78 to 2.92 (low) in the degraded and 3.51 to 3.55 (low) in non-degraded for Ochobo I.Ochobo II had values varied from 2.19 to 2.50 (low) in the degraded and 3.44 to 3.60 (low) in non-degraded. The Mg^{2+}

values ranged from 2.14 to 2.29 in the degraded and 2.85 to 2.97 in non-degraded for Ochobo I. The degraded area in Ochobo II had values range from 2.11 to 2.44, the non-degraded area values varied between 2.96 to 2.98. The Na+ content ranged from 0.21 to 0.24 in the degraded, and 0.18 to 0.20 in non-degraded for Ochobo I, while Ochobo II had its range from 0.22 to 0.23 in the degraded and 0.20 in non-degraded. The K+ content ranged from 0.28 to 0.34 (moderate) in degraded and 0.29 to 0.31 (moderate) in the non-degraded for Ochobo I. The degraded and non-degraded areas were rated low in Ochobo II, having values between 0.21 to 0.24, and 0.27 to 0.29 respectively. Calcium was the dominant exchangeable base in all the soils. The low values obtained in some depth may be due to cation removal by plant uptake or leaching. Generally, surface soils recorded higher values than underlying subsoils, which could be attributed to plant uptake and minimal leaching in the soils. This is contrary to Shobayo, (2010) who reported that the calcium content of surface horizon was lower than subsoils. Similar result was reported by several researchers (Hussaini, 2011; Singh *et al*., 2013). The predominance of Ca was partly due to exchange sites having high affinity for Ca and also due to calcium bearing parent material (Nahusenay *et al.,* 2014).
The increasing acidity with soil depth could be a serious threat to root development and proliferation.

Cation exchange capacity

The CEC values for the soils of Ochobo I was from 7.34 to 8.44 in the degraded, and 9.36 to 10.88 in non-degraded, while that of Site II was from 9.80 to 9.91in the degraded, and 10.00 to 10.03 in non-degraded. The CEC value decreased with depth from the surface soils to the sub surface soils in all the sites examined. The CEC values of the non-degraded soils were rated higher than those of the degraded soils which could be attributed to high clay content in non-degraded areas. Low values were reported to be an indication of dominance of sesquioxide and kaolinitic clays in the fine earth fractions (Tan, 2000). The exchange sites were dominated by Ca followed by Mg, probably because of soils" affinity for these cations. Similar findings were reported by Ita and Esu (2012) on coastal plain sand in southeastern Nigeria. The high CEC values of A-horizons may be attributed to low leaching in the study area. Generally, effective CEC (ECEC) followed the same pattern as that of CEC (NH4OAc) whose values decreased with depth. The application of the organic residue and the avoidance of bush burning are management practices that play important role in reversing the trend of nutrient depletion. Other practices are; conservation tillage system (Haine and Urem, 1990) and the establishment of mulches (Lal, 1986).

Base saturation

The result in (Table 4), indicated that the base saturation was high (66.82 to 75.75 % and 63.79 to 74.25 %) in the degraded, and non-degraded (48.37 to 54.49 % and 68.90 to 70.29 %) areas of Ochobo I and II respectively. The values imply that the soils were high in native fertility in terms of base saturation.

Interpretations of soil chemical properties

The interpretations of the soil chemical properties were based on the guidelines (FAO, 2004) Table 2 (a-i). These guidelines provide different ratings for the assessment of the soil quality indicators. The measured soil chemical properties were compared to the FAO (2004), documented evaluation guideline.

Soil reaction (pH)

The results in Table 2 compared with the standard in Table 2 f which indicates that the soils were rated strongly acidic in the degraded areas of Ochobo I and II, and non-degraded Ochobo I.

Soil organic carbon (OC) content

The values of organic carbon for Ochobo I was rated high (1.5-2.0), while the rest of the Sites were rated low (0.4-1.0).

Soil total nitrogen content

The fertility rating indicated that nitrogen rated low (0.1-0.2 %) in non-degraded Ochobo II. For the degraded Ochobo II, the rating was very low (<0.1 %). The value was rated high (0.5 – 1.0 %) for non-degraded Ochobo I.

Available phosphorus

The soils indicated low available phosphorus content for both the degraded and non-degraded areas in all the Sites studied, as the values were less than 8 mg/kg.

Exchangeable cations

Calcium content was low in both the degraded and non-degraded sites of Ochobo I and II. The Magnesium contents rated moderate for both degraded and non-degraded Sites of Ochobo.The values for Sodium indicated low rating in both, the degraded and non-degraded Sites of Ochobo. Potassium values indicated low for degraded and non-degraded Ochobo sites I and II.

Table 5: Soil quality indicators (qi) for land degradation assessment.

Locations	Depth (cm)	B.D (g/cm^3)	K_{Sat} (cm/hr)	B.Sat (%)	TN (%)	Av.P (mg/kg)	K (cmol/kg)	ESP (%)	OC (%)
Ochobo I Degraded	0-15	1.41	7.50	66.82	0.41	5.22	0.34	2.84	2.21
	15-30	1.49	5.60	75.75	0.04	5.00	0.28	2.86	0.84
Non degraded	0-15	1.28	8.70	63.79	0.72	6.34	0.31	1.84	4.78
	15-30	1.31	7.60	74.25	0.41	4.36	0.29	1.92	2.31
Ochobo II Degraded	0-15	1.47	8.20	54.49	0.06	3.30	0.24	2.22	0.64
	15-30	1.52	5.20	48.37	0.06	3.23	0.21	2.35	0.58
Non degraded	0-15	1.20	9.70	65.73	0.11	4.70	0.29	2.22	1.09
	15-30	1.21	7.50	70.94	0.09	5.20	0.27	2.34	0.86
	15-30	1.51	6.00	55.80	0.03	4.00	0.13	3.80	0.27

Source: Field Survey, 2020

Table 6: Assessment of individual soil quality indicators (QI)

Locations	Depth (cm)	B.D (g/cm^3)	K_{Sat} (cm/hr)	B. Sat (%)	TN (%)	Av.P (mg/kg)	K (cmol/kg)	ESP (%)	OC (%)
Ochobo I Degraded	0-15	SD	MD	MD	SD	VHD	SD	SD	MD
	15-30	SD	MD	MD	VHD	VHD	SD	SD	VHD
Non degraded	0-15	SD	MD	SD	SD	HD	SD	SD	SD
	15-30	SD	MD	SD	SD	VHD	SD	SD	MD
Ochobo II Degraded	0-15	SD	MD	MD	VHD	VHD	SD	SD	VHD
	15-30	MD	MD	MD	VHD	VHD	SD	SD	VHD
Non degraded	0-15	SD	MD	SD	MD	VHD	SD	SD	HD
	15-30	SD	MD	SD	HD	VHD	SD	SD	VHD

Key: SD = Non - Slightly degraded, MD = Moderately degraded, HD = Highly degraded, VHD = Very highly degraded

Cation exchange capacity (CEC) of the soils

CEC as compared with the standard (Table 2b) was low in all the sites studied.

Base saturation

Base saturation rated high in both non degraded and degraded sites in Ochobo.

Saturated hydraulic conductivity (K_{Sat})

The K_{Sat} values of the degraded and non-degraded soils of Ochobo sites I and II indicated moderate permeability (Tables 5 and 6).

Conclusion and Recommendations

Increasing land degradation leads to the sensitivity of the land surface to wind and water erosion that are evident by the presence of rill and gully erosion, tree-root and rock exposure, soil build-up against structures, formation of pedestals, changes in colour (darker to lighter), exposure of fragipan or armour layer which has serious negative impact on the environment and public health. The results of this study showed clearly the state of land degradation; which include fertility decline, soil erosion and settlements in the study areas. These are of serious constraint to both arable and tree crop production without proper land management practices. Sustainable cropping on the studied soils can be achieved with proper management of crops residues, fallow periods, introduction of leguminous cover crops in the farming system and organic matter incorporation (to partly reduce Al toxicity). This study is a further proof that soil research and documentation of soil resources, although capital intensive produces a better scientific basis for soil management rather than generalized recommendations. Rehabilitation endeavors (mechanical and/or agronomic practices) should be directed to areas of severely degraded land and also to areas that are not at high risk to lessen the overall effect of degradation.

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Appendix 1: Indicators and criteria for soil degradation assessment (FAO, 1979).

	Degree of Degradation			
	1	**2**	**3**	**4**
Productivity level	100-75	75-50	50-25	25-10
Remarks	SD	MD	HD	VHD
Indicators				
Bulk Density	<1.5	1.5-2.5	2.5-5	>5
Permeability	<1.25	1.25-5	5-10	>10
Nitrogen	>0.13	0.13-0.10	0.10-0.08	<0.08
Phosphorus	>8	8-7	7-6	<6
Potassium	>0.16	0.16-0.14	0.14-0.12	<0.12
ESP	<10	10-25	25-50	>50
Base Saturation	<2.5	2.5-5	5-10	>10
Organic Matter	>2.5	2.5-2	2-1.0	<1.0

SD = None to slightly degraded, MD = Moderately degraded, HD = Highly degraded, VHD = Very highly degraded.