Characterization of Soils of Ifite Ogwari Campus of Nnamdi Azikiwe University, Anambra State, South Eastern Nigeria

Nnabuihe, E. C.[1], Nwadibia, M. U.[1], Nwosu, T.V.[1], Okafor, M.J.[1], Ibeh, C.U.[1], Ibigweh, M.N. [1], Nwaiwu, C. J. [1], Nwankwo, J. E[1]. and Osujieke, D. N.[2]*

[1]*Department of Soil Science and Land Resources Management, Nnamdi Azikiwe University Awka Anambra state Nigeria*
[2]*Department of Soil Science and Land Resources Management, Federal University Wukari Taraba state Nigeria*

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*CORRESPONDING AUTHOR

emmannabuihe@gmail.com

ABSTRACT

This study assessed the properties of soils under arable (profile 1), pasture (profile 2) and forested (profile 3) lands at Nnamdi Azikiwe University Ifite Ogwari campus (latitude 06° 60' 13" N and longitude 6° 95' 63" E) to investigate the morphological, physical and chemical properties and determine relationships among them. A total of 12 samples were collected according to horizon differentiation. Soil samples were examined using standard laboratory procedures and data generated were analyzed using coefficient of variation and correlation to determine their relationships. Textural class of arable and pasture lands ranged from loam to sandy loam and forested land from loamy sand to sandy loam. Mottles colour were observed in pasture and forested lands. Variability in pH of arable, pasture and forested lands was 3.85 %, 3.64 % and 0.90 % respectively. The coefficient of variation of organic carbon content was 16.99 %, 39.59 % and 52.50 % in arable, pasture and forested lands respectively. The variability in base saturation was low in arable land (15.24 %) and pasture land (15.12 %) and moderate in forested land (26.88 %). The Organic carbon content correlated with Total nitrogen (TN) and Available phosphorus (AP) in arable and pasture lands and TN, AP and Na in forested land. The soils have low nutrient reserves and use of organic soil fertility management (dungs and composts) was recommended for farmers to increase yields in arable land, improve pasture land and conserve forested land.

INTRODUCTION

Information relating to soil conditions, their current status, changes as a result of land use and management practices is critical for sustainable agriculture, because it is important for proper planning and management of soils. It is imperative to take cognizance of soil properties for planning suitability of crops and reduce massive land deterioration and degradation which hampers the sustainability of soil resources. In recent times forest lands have been affected because of over exploitation as a result of timber production, firewood, expansion of cultivated and grazing lands, resulting in decline of soil fertility and crop production. The indiscriminate use of land can lead to environmental problems such as food insecurity, health and safety hazards and depressed viability of the earth for food production. There should be prior knowledge of soil properties since farmers in Ifite Ogwari use land for various purposes which partly destroy soil structure and reduces fertility and long-term use of soil. Detailed soil survey is a prerequisite for sustainable agricultural development. This study is imperative since population is increasing geometrically with a fixed land mass and there is need to adopt effective land practices by farmers and guidelines for land users for proper land use planning. The objective of the study was to determine the properties of soils of different land use in Ifite Ogwari. The specific objectives of the study were to investigate the morphological, physical and chemical properties of soils of arable land, pasture land and forested land and inter-correlate these soil properties to determine relationships among them.

MATERIALS AND METHODS

The study was conducted at Faculty of Agriculture Nnamdi Azikiwe University Ifite Ogwari Campus (Lat. 06° 60' 14" N and long. 6° 95' 02" E, elevation: 42 MASL) in Ayamelum L.G.A of Anambra state. The geology consists of Lower coal measure, False - bedded sandstone and Imo clay shales (Orajaka, 1975). The hydrology includes floodplains of Omambala River, Ezu River, Du-River and Obina River (Ofomata, 1975). The area has a tropical wet-and-dry climate of Koppen's Aw-type (Inyang, 1975), average annual rainfall of 1700 mm and average mean temperature of 29.0 ^{o}C (NIMET, 2022). The vegetation is that of secondary forests-savannah mosaic, as anthropogenic activities have reduced the density of these forests. (Igbozuruike, 1975). The soils of Ifite Ogwari are generally sandy with accumulation of clay and gravels in most subsurface horizons and moderately to imperfectly drained. The sites include arable land (continuously planted in rotation with rice, maize and pigeon peas), pasture land (mostly of elephant and guinea grasses with few shrubs) and forested land (mainly *Gmelina arborea, Melicia excelsa, Tectona grandis and Ceiba pendandra* trees and woodlands). Profile description was according to horizon boundaries delineation based on the guidelines of FAO (2006). Soil samples were collected from each of the constituent horizon, labeled, air dried, crushed, sieved using 2 mm sieve, re-bagged and sent to the laboratory for analysis. The undisturbed soil samples were used for bulk density and saturated hydraulic conductivity determination.

Laboratory Analyses

Particle size distribution by hydrometer method (Gee and Or, 2002). Bulk Density by core method (Grossman and Reinsch, 2002). Moisture content (Obi, 1990). Saturated hydraulic conductivity by constant head parameter method (Topp and Dane, 2002). The soil pH using pH Meter in 1:2:5 ratio of soil to water (Thomas, 1996). Total nitrogen by Kjeldahl digestion method (Bremmer 1996). Organic carbon by wet digestion method (Nelson and Summers, 1982). Available phosphorus by Bray II method (Olsen and Sommers, 1982). Exchangeable (Ex) base by extracting with 1N NH_4O_{AC} solution, Ex. Ca and Mg by EDTA Complexometric titration. Ex. K and Na by flame photometry (Jackson, 1962). Cation exchange capacity (CEC) by aluminum acetate leaching at pH 7 (Blackemore *et al*., 1987). Total porosity = (F) = 1 – $\underline{e_b}$ / e_s x 100/1, Where: e_b = bulk density (M g/cm^3) and e_s = particle density (2.65 Mg/cm^3). Base saturation (% BS) = TEB/CEC * 100/1.

Statistical Analysis

The GENSTAT statistical package version 12 was used. The coefficient of variation (CV) (%): 0-15 (low variation), 16-35 (moderate variation), 36-100 (high variation) (Wilding *et al*., 1994) and Pearson correlation were used to determine relationships among soil properties.

RESULTS AND DISCUSSION

Results of soil morphological properties are presented in Table 1. Colour varied as strong brown in A (7.5YR 5/6), light brown in AB (7.5YR 6/4), Pale red (7.5YR 7/4) in Bt1 and light red (10YR 6/6) in Bt2 horizons of arable land. Pasture land was reddish yellow in A (7.5YR 6/8), light brown in AB (7.5YR 6/4), yellowish brown in Bt1 (10YR 5/6) and brown in Bt2 (7.5YR 5/4) horizons. Forested land was dark yellowish brown in A (10YR 4/4), brown in AB (7.5YR 5/4), reddish brown in Bg1 (5YR 5/3) and yellowish red in Bg2 (5YR 5/6) horizons. There were reddish yellow (A) and red mottles (Bt1 and Bt2) and red (A, AB and Bg2) and reddish gray (Bg1) mottles in pasture and forested lands respectively. Structure varied as weak, very fine crumb in A horizon of arable, pasture and forested lands, weak, very fine sub angular blocky in AB and Bt1 horizons of arable land and Bt2 horizon of pasture land, weak, fine and sub angular blocky in Bt1 horizon of pasture land, moderate, medium, sub angular blocky (Bt2 horizon of arable land, Bg2 of pasture land), moderate, very fine crumb (AB horizon of pasture land) and moderate, fine and sub angular blocky (AB and Bg1 horizons of forested land). The moist consistencies were friable (A, AB, Bt1 horizons of arable land, A, AB and Bt2 horizons of pasture land and AB horizon of forested land) and firm (Bt2 horizon of arable land, Bt1 horizons of pasture land and A, Bg1 and Bg2 of forested land) in most horizons. Root activities varied as fine and medium and very fine and few in arable and pasture lands respectively and fine and few (A and Bg1) and very fine and few (AB) in forested land. Soils were well drained in most horizons, moderately drained in Bt1 of pasture land and poorly drained in Bg1 and Bg2 of forested land. Horizon boundaries were wavy and clear (A, AB and Bt1 horizons in arable land), smooth and clear (AB horizons of pasture land) and smooth and diffuse (A and Bt1 horizons of pasture land and A, AB and Bg1 of forested land). Soils of forested land were brownish on the surface horizons (0 – 12 cm) and reddish to brownish (12 – 50 cm) at the argillic horizons than arable and pasture lands. This was a result of organic matter influence on soil colour. Mottles colour was due to poor drainage condition, yellowish and reddish colours signified the presence of sesquioxides while pale colour was eluviation or leaching of basic cation and organic matter (Esu, 2010). Variation in structure was due to movement of clay and minerals and bulk density in soils. Crumb structure of soils could be due to continuous addition of organic matter while sub angular blocky nature could be attributed to clay fractions. Presence of plant roots in surface and subsurface horizons was due to the presence of fibrous roots dominance. Boundary forms was a result of lateral movement of soils (Esu, 2010).

Table 1 Macro morphological Properties of Pedons in Ifite Ogwari sites.

Horizon	Depth (cm)	Matrix Colour (moist)	Mottles	Structure	Consistence (moist)	Roots	Drainage	Boundary form
Arable Land (Profile 1)								
A	0 – 17	SB 7.5YR 5/6	-	1, vf, cr	Friable		wd	w, c
AB	17 – 33	LB 7.5YR 6/4	-	1, vf, sbk	Friable	f, m	wd	w, c
Bt1	33 – 54	PR 7.5YR 7/4	-	1, vf, sbk	Friable		wd	w, c
Bt2	54 – 152	LR 10YR 6/6		2, m, sbk	Firm	-	wd	-
Pasture Land (Profile 2)								
A	0 – 20	RY 7.5YR 6/8	RY	1, vf, cr	Friable	-	pd	s, d
AB	20 – 44	LB 7.5YR 6/4	-	2, vf, cr	Friable	vf, fw	wd	s, c
Bt1	44 – 73	YB 10YR 5/6	R	1, f, sbk	Firm	-	md	s, d
Bt2	73 – 158	B 7.5YR 5/4	R	1, vf, sbk	Friable	-	wd	-
Forested Land (Profile 3)								
A	0 – 12	DYB 10YR 4/4	R	1, vf, cr	Firm	f, fw	wd	s, d
AB	12 – 20	B 7.5YR 5/4	R	2, f, sbk	Friable	vf, fw	wd	s, d
Bg1	20 – 50	RB 5YR 5/3	RG	2, f, sbk	Firm	f,fw	pd	s, d
Bg2	50 – 150	YR 5YR 5/6	R	2, m, sbk	Firm	-	pd	-

Key: colour (moist): B = brown, RB = reddish brown, YR = yellowish red, LB = light brown, RY = reddish yellow; RG = reddish gray; PR = pale red, R = red, YB = yellowish brown; Structure: sbk = sub-angular blocky, cr = crumb; 1= weak, 2 = moderate; vf = very fine, m = medium, f = fine, Roots: f, m = fine, medium; vf, fw = very fine, few; f, fw = fine, few; vf, fw = very fine, few; f, m, fine, medium. Drainage: wd = well drained, md = moderately drained, pd = poorly drained; Boundary form: w, c = wavy, clear; s, c = smooth, clear; s, d = smooth diffuse

Physical properties of soils

The physical properties of soils are shown in Table 2. Texture ranged from sandy loam to loam in arable and pasture lands and sandy loam to loamy sand in forested land. Sand fraction had moderate variation in arable (CV = 25.32 %), pasture land (CV = 24.37 %) and forested land (CV = 17.09 %). Clay varied highly in arable land (CV = 53.42 %), pasture land (CV = 50.12 %) and forested land (CV = 39.55 %). Moisture content (MC) increased irregularly across profiles with moderate variation in arable (CV = 18.64 %), pasture land (CV = 34.48 %) and forested land (CV = 25.50 %). Bulk density increased across profiles with low variations in arable land (CV = 6.22 %), pasture land (CV = 7.06 %) and forested land (CV = 2.37 %). Total porosity varied minimally in arable land (CV = 7.29 %), pasture land (CV = 9.14 %) and forested land (CV = 2.81 %). The

KSat values varied from low variation in pasture land (CV = 11.45 %) to moderate in arable (CV = 18.71 %) and forested land (CV = 29.96 %) but decreased irregularly across the profiles. Table2 showed that sand dominated other fractions as reflected in the textural class of the soils which reflects their parent materials.

The accumulation of clay in subsoils was due to the lateral movement or surface erosion. High silt values obtained from pasture and forested lands indicated low degree of weathering (Esu, 2010). Low bulk density values of soils were attributed to organic matter deposition and sorting of material. Total porosity values in soils reflected an inverse relationship with bulk density. The values of KSat was attributed to macro pores, organic matter content and low bulk density of soils.

Table 2 Physical Properties of Pedons in Ifite Ogwari sites

Horizon	Depth	sand	Silt	Clay	TC	MC	BD	TP	KSat
	(cm)	←	%	→		(%)	Mg/m^3	%	cm/min
Arable Land (Profile 1)									
A	0-17	80.93	14.33	4.74	LS	0.09	1.30	50.94	0.98
AB	17-33	64.72	20.24	15.04	SL	0.13	1.50	43.40	0.72
Bt1	33-54	53.80	26.13	20.04	SL	0.14	1.45	45.28	0.76
Bt2	54-152	45.01	30.00	24.99	L	0.11	1.47	44.53	0.64
	Mean	61.12	22.68	16.20	SL	0.12	1.43	46.04	0.78
	CV (%)	25.32	30.25	53.42		18.64	6.22	7.29	18.71
Pasture Land (Profile 2)									
A	0-20	46.92	30.05	23.03	L	0.15	1.40	47.17	1.06
AB	20-44	39.92	35.04	25.04	L	0.09	1.30	50.94	1.00
Bt1	44-73	54.92	30.04	15.04	SL	0.13	1.50	43.40	0.82
Bt2	73-158	70.60	23.38	6.02	SL	0.21	1.55	41.51	0.89
	Mean	53.09	29.62	17.29	SL	0.15	1.43	45.76	0.94
	CV (%)	24.37	16.15	50.12		34.48	7.06	9.14	11.45
Forested Land (Profile 3)									
A	0-12	66.50	20.44	13.06	SL	0.13	1.40	47.17	1.26
AB	12-20	53.82	28.14	18.04	SL	0.20	1.44	45.66	0.72
Bg1	20-50	60.92	30.04	9.04	SL	0.13	1.42	46.42	0.94
Bg2	50-150	80.20	12.30	7.50	LS	0.18	1.48	44.15	0.67
	Mean	65.36	22.73	11.91	SL	0.16	1.44	45.85	0.90
	CV (%)	17.09	35.62	39.55		22.50	2.37	2.81	29.96

Key: TC=textural class: SL= sandy loam, SCL= sandy clay loam, L = loam, LS = loamy sand, MC = moisture content, BD = bulk density, TP = total porosity, KSat = saturated hydraulic conductivity, LV = low variation, MV = medium variation, HV = high variation

Chemical properties of soils

The chemical properties of soils are shown in Table 3. The pH of soils was strongly to moderately acidic with low variation in arable (CV= 3.85 %), pasture land (CV= 3.64 %) and forested land (CV= 0.90 %). Organic carbon contents of soils had moderate variation in arable (CV = 16.99 %) and high variation in pasture (CV = 39.59 %) and forested land (CV = 52.50 %). Total nitrogen values were moderate in arable (CV = 29.69 %) and high in pasture (CV = 59.07 %) and forested (CV = 55.13 %). Variability of available phosphorus was least in arable land (CV = 1.69 %), moderate in forested land (CV = 27.78 %) and high in pasture land (CV = 41.67 %). Variability of Ca^{2+} (CV = 9.79 %) and Mg^{2+} (CV = 14.01 %) was low while Na^{+} (CV = 61.58 %) and K^{+} (CV = 98.18 %) was high in arable land. In pasture land variability of Ca^{2+} (CV = 34.57 %) and Na^{+} (CV = 41.67 %) was high, Mg^{2+} was low (CV = 9.91 %) while K^{+} (CV = 34.29 %) was moderate. The Ca^{2+} (CV = 29.54 %) and Mg^{2+} (CV = 20.23 %) in forested land varied moderately, Na^{+} (CV = 61.58 %) and K^{+} (CV = 98.18 %) varied highly. The CEC varied minimally in arable land (CV = 7.25 %), pasture land (CV = 11.08 %) and forested (CV = 11.25 %). The base saturation was least in arable land (CV = 15.24 %) and pasture land (CV = 15.12 %) and moderate (CV = 26.88 %) in forested land. From the results soil reactions (pH) were generally acidic and could be due to leaching of basic cations. Average organic carbon content was below critical level (2 - 3 g/kg) for tropical soils (Landon, 1991). Arable and forested land average TN values were higher than pasture land and could be linked to high organic carbon content of soils. Available phosphorus values were generally low (< 3 mg/kg) (FDALR, 1990) and could be due to sorption reaction of soils. Exchangeable Ca^{2+} dominated in soils but was < 4 cmol/kg critical limit (FDALR, 1990). Exchangeable Mg^{2+} and Na^{+} were rated low (0.3 – 1.0 cmol/kg) and very low (< 0.10 cmol/kg) respectively in all pedons studied and fell below critical limits for fertile soils while forested land was rated low (0.2 – 0.3 cmol/kg) (FDALR, 1990). The CEC values were low (6 - 12 cmol/kg) (FDALR, 1990) due to leaching, low organic carbon and clay contents which hold nutrients in these soils. Base saturation of soils was rated low (20 – 40 %) for pasture and forested land and moderate (40 – 60 %) for arable land (FDALR. 1990).

Table 3 Chemical Properties of soils of Ifite Ogwari study sites

Horizon	Depth (cm)	pH	OC g/kg ←	TN →	AP Mg/kg	Ca Cmol/kg	Mg ←	Na	K	H	Al	TEB →	CEC	BS %
Arable Land (Profile 1)														
A	0-17	5.50	3.50	0.34	0.018	2.85	1.65	0.184	0.02	0.18	0.09	4.71	9.98	47.19
AB	17-33	5.10	4.40	0.39	0.022	2.70	1.40	0.226	0.23	0.38	0.19	4.55	9.92	45.87
Bt1	33-54	5.10	3.30	0.23	0.017	2.62	1.20	0.178	0.18	0.22	0.43	4.18	10.66	39.21
Bt2	54-152	5.10	3.00	0.21	0.015	2.25	1.60	0.015	0.02	0.43	0.24	3.88	11.56	33.56
	CV (%)	3.85	16.99	29.69	1.69	9.79	14.01	61.58	98.18	40.32	60.25	8.61	7.25	15.24
Pasture Land (Profile 2)														
A	0-20	5.00	3.80	0.36	0.019	1.62	1.88	0.019	0.21	0.282	0.14	3.73	13.15	28.37
AB	20-44	5.20	2.30	0.16	0.012	2.50	1.70	0.012	0.13	0.386	0.20	4.34	11.92	36.41
Bt1	44-73	5.40	2.00	0.14	0.010	1.12	1.50	0.010	0.11	0.190	0.10	2.74	10.03	27.32
Bt2	73-158	5.40	1.60	0.11	0.008	2.42	1.58	0.008	0.11	0.224	0.11	4.12	11.45	35.98
	CV (%)	3.64	39.59	59.07	41.67	34.57	9.91	41.67	34.29	31.73	32.85	18.97	11.08	15.12
Forested Land (Profile 3)														
A	0-12	5.60	3.80	0.33	0.02	2.50	1.50	0.019	0.21	0.250	0.40	4.22	10.60	39.81
AB	12-20	4.90	4.40	0.37	0.02	2.50	1.00	0.022	0.23	0.267	0.43	3.75	9.12	41.12
Bt1	20-50	4.90	3.00	0.30	0.02	1.20	1.12	0.015	0.18	0.267	0.40	2.51	11.97	20.97
Bt2	50-150	4.90	0.80	0.05	0.01	2.10	1.50	0.004	0.04	0.180	0.37	3.64	10.20	35.69
	CV (%)	0.90	52.50	55.13	27.78	29.54	20.23	53.33	52.15	17.01	6.00	20.54	11.25	26.88

Key: pH H_20= pH in water, TN=total nitrogen, AP=available phosphorus, TEB=total exchangeable bases, CEC=cation exchange capacity

Correlation coefficients of soils

Pearson correlation matrix of soils in arable had Clay correlated and positively with moisture content (MC) and negatively with total nitrogen (TN). The organic carbon (OC) content was positive and highly significant with TN (**0.9041) and available phosphorus (AP) (**0.9956). In pasture land Clay was highly significant with MC (**- 0.8436) and total porosity (TP) (**0.9003) and significant with TN (*0.5961). The OC content was highly significant with positive and negative correlations with TN (**0.9926) and AP (*-0.9956) respectively. In forested land Clay correlated positively and highly significantly with TP, OC and TN and significantly with AP. Total nitrogen (TN) was highly significant and correlated positively with K (**0.9971).

CONCLUSION AND RECOMMENDATIONS

Results of soil properties of study sites showed that different land use varied with soil properties. The order followed a decreasing style as in OC and AP: Arable land > forested land > pasture land, Ex. K: Pasture land > forested land, CEC: Pasture land > forested land > arable land and Base Sat: Arable land > forested land > pasture land. Since these soils have low nutrient reserves, it was therefore recommended that the use of organic soil fertility management (dungs and composts) be adopted by farmers to increase yields in arable land, improve pasture land while forested land is conserved.

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