ASSESSMENT OF FERTILITY RATIOS OF SELECTED SOILS OF ABIA STATE, SOUTHEASTERN NIGERIA

Chukwuma, Michael C.
Department of Soil Science and Technology, Federal University of Technology, Owerri, Nigeria
Email Address: chukwumamike@yahoo.co.uk, michaelchigboguchukwuma@gmail.com
Phone:07035058211

ABSTRACT
The study was to investigated soil fertility of some soils of Abia State, Nigeria using selected elemental ratios. Guided by geology map of the state, target soil survey method was employed to locate soil profiles in Akwaete, Alayi, Ibeku, Owerrinta and Uzuakoli. These soil profiles were delineated, described and sampled using FAO procedures. Soil samples were prepared prior to laboratory analyses. Fertility indices were measured in the laboratory. Generated soil data were subjected to descriptive statistics of mean and coefficient of variation. Carbon-Nitrogen ratio was also irregular with higher values at epipedons of all the soils, with most having a mean value of 12:1 in epipedons. Soils were not fertile as Calcium-Magnesium ratio was less than 3.0 in all soils except in soils of Uzuakoli with ratio of 3.43:1 The K/Mg ratio of the studied soils varied from 0.2 to 0.53 and is within the acceptable range for crop production. Higher values of Ca+Mg+K+Na/Al+H recorded in Ibeku profile indicated greater concentration of basic cations than total acidity. Aluminium: cation exchange capacity of the soils varied among soil profiles. The Fe/Mn had mean values of 3.25, 2.92, 2.42, 1.46, 2.63 and 2.08 in profile against critical ratio of 2:1.
Keywords: Assessment, Elemental ratios, Fertility, Soils

INTRODUCTION

There is declining soil fertility in most tropical soils. This heightened by erosive rainfalls in the region with associated leaching and runoff losses. Onweremadu *et al*.(2024) reported that leaching occupies a prominent pedogenic process inherent in tropical soils, causing nutrient imbalances and loss of basic cations.They observed changes in exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}), exchangeable potassium (K^{+}) and exchangeable sodium (Na^{+}) and these are translocated from epipedal horizons of the soilsphere towards endopedons beyond the reach of most crops particularlay arable crops and other shallow-rooted plants. According to Malvi (2011), there is a pre-determined ratio of nutrients required by plants depending on its life cycle, environment and genotypic characteristics to attain the crop's maximum genetic potential. Due to this, many nutrient ratios have been identified, they include: Ca: Mg (3: 1), K: Mg (1:1), P: S (1: 1), P: Zn (10:1) and Fe: Mn (2:1) ratios.

Calcium to magnesium ratio (3:1) is one of the most important ratios in soils, determining the gaseous exchange in soils for better photosynthesis in crops. The exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}) are needed in balanced proportion as high magnesium concentration in soils may inhibit the activity of aerobic microorganisms in the soil (Sait, 2015a). Tit is important to remark that Ca: Mg ratios recommended for sandy soils is 3: 1 and clayey soils is 7:1 (Philips, 2021; Osemwota *et al*., 2007).

In the same vein, potassium to magnesium ratio (1:1) is regarded as another important ratio, whose presence may influence the uptake of another element either negatively or positively. The presence of high exchangeable magnesium in certain soils, inhibits the uptake of potassium and vice versa, leading to poor yields. However, adequate ratio of the two nutrient element enhances optimum growth and development of crops (Järvan, 2004).

Essel *et al*. (2021) stressed the the need for balanced phosphorus to sulphur ratio in soils. Although the ratio is often neglected, sulphur has been found deficient in soils uner the influence of acid rains from industrial operations. Thus, there is the need to optimize P:S ratio for proper crop nutrition (Essel *et al*., 2021).

Sait(2015b) identified iron to manganese ratio as very vital especially for microelements nutrition in plants. Iron and manganese are essential micronutrients for plant resilience. Iron and manganese are antagonistic to each other, hence excess manganese in the soil could lead to iron deficiency (Sait, 2015b; Essel *et al*., 2021).

Philips (2021 emphasized the importance of phosphorus to zinc ratio**.** High phosphorus levels in soils can inhibit zinc uptake and result in poor yields of crops. However, ideal P: Zn recommended ratio for crops is 10: 1 (Essel *et al*., 2021; Philips, 2021).

States in Nigeria have consequences of soil nutrients deficit due to lack of adequate synthetic-fertilizer input, limited return of organic residues and manure to farmlands. The situation is worsened by high biomass removal from farm lands, high soil erosion rate, and leaching loss of nutrient elements. Generally, there is limited quantitative knowledge of the relationship existing between these nutrient elements in these soils. Consequently, the major objective of this study was to investigate soil fertility of some soils of central southeastern Nigeria using selected elemental ratios.

MATERIALS AND METHODS

Study Area

The study was conducted at six different locations which are underlain by three major lithological materials; falsebedded sandstone, coastal plain sands and shale in Abia State (Akwette, Alayi, Ibeku, Nkporo, Owerrinta and Uzuakoli), , southeastern Nigeria. The study area lies within Latitudes 4°45'N and 7°15'N and Longitudes 6°50'E and 7° 30'E.

Geology and geomorphology

The soils of the study area are mostly derived from coastal plain sands (Benin Formation), shale (Bende - Ameki Formation), falsebedded sandstones (Ajali formation) The area has generally lowland geomorphology, less than 150 m above sea level. The Northeastern part of the area is characterized by rising hilly topography.

Climate: Abia State lies within the humid tropical climate. Tropical climate is characterized by rainy season (February/March – November) and dry season (November – February/March). Annual rainfall of the area is about 2,500 mm along the Atlantic coast, The temperature pattern has mean daily and annual temperature as 27°C and 30°C, respectively, while the average relative humidity ranges between 60-70% and 80-90% in January and July, respectively (NIMET, 2014).

Vegetation

The vegetation is a typical rainforest with a variety of plant species. The natural rainforest vegetation that previously characterized the study area is gradually receding to derived savannah due to human activities. The natural vegetation in the study area consists of some tree species that are remnants of a once dense evergreen forest occurring on slopes and sparse grass complex in various spots. Oil palm (*Elaeis guineensis*) is a dominant tree type in the area. Other plant species include pawpaw (*Carica papaya*), mango (*Mangifera indica*), native peas (*Dacryodes edulis)*,African breadfruit (*Treculia* spp.).raphia (*Raphia hookeri*), *Dactylademia barterri* and *Anthonata macrophylla*are .

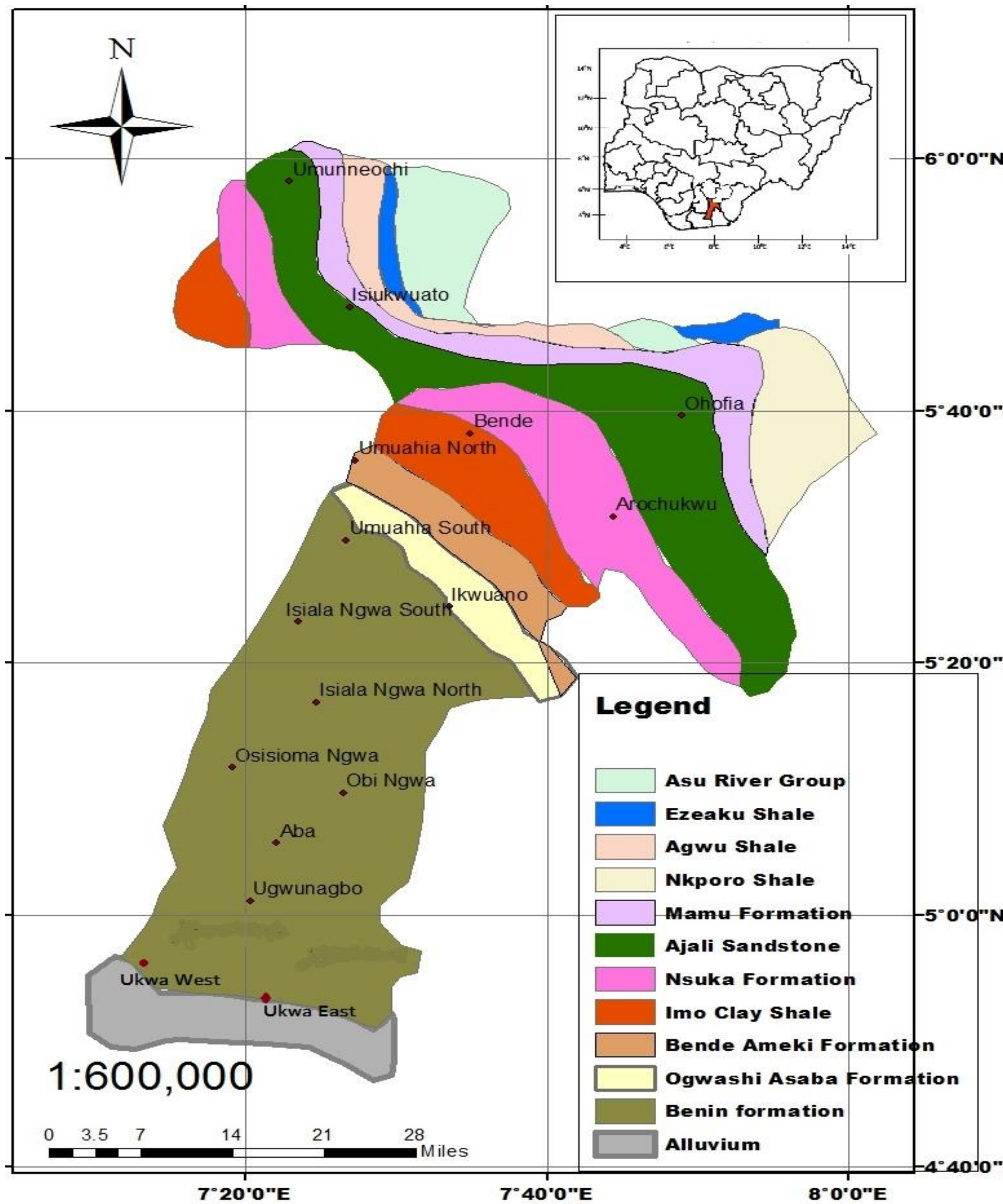

Figure 3.5: Geology Map of Abia State (Source: NEWMAP, 2017)

Socioeconomy

Abia State is mainly agrarian especially in the rural areas. As agriculture is a major socio-economic activity of the area, about 70% of the total area is used as cultivated land. Slash-and-burn technique has been the major method of land clearing, whereas bush fallow is a soil fertility regeneration practice that has prevailed for over 10 decades. The land use consisted of a mixture of bush regrowth and arable crops. Most of the people in the district are engaged in mixed crop-livestock agriculture. Crop production is entirely rain-fed, except in some very specific and small areas where vegetables are grown using traditional small-scale irrigation. The most commonly produced crops in the study area are annual crops such as *Manihot spp*., *Zea mays* L., *dioscorea spp*., *Phaseolus spp*. Perennial crops including *Musa spp,* oil palm (*Elaeis guineensis*) and native peas (*Dacryodes edulis)* are also found in this area. Although very few of the farmers use inorganic fertilizers (Onweremadu, 2007). Other activities include fishing, trading, white collar jobs, manufacturing, welding, artisanry and sand mining.

Field studies

Target soil survey technique guided by Geological map was used in field soil sampling. A soil profile was sunk in soils of each of the six communities with three different lithological materials in the study area. A total of eighteen soil profiles were used for the study which served as the representative pedons in the three parent materials. All soil profiles were geo-referenced using handheld Global Positioning System (GPS) Receiver (Garmin Ltd,Kansas USA).

Profile pits were described and sampled according to genetic horizons for characterization and classification (FAO, 2006; Soil Survey Staff, 2014). Soil samples were collected from the bottom-most horizon to the topmost to avoid contamination of soils from the horizons. Soil color was determined using the Revised Munsell Soil Color Chart (Munsell Soil Color Chart, 1994). Soil structure was described in terms of the sequence: grade, size, and type (shape) of aggregates whereas horizon boundaries were described in terms of depth, distinctness, and topography. The soil consistence was identified at dry, moist and wet moisture conditions.

Samples were collected with core samplers for bulk density and moisture content analyses. The soil samples collected from the study area were bagged, labeled and transported to the laboratory for preparation and analysis of selected soil properties following standard laboratory procedures. In preparation for laboratory analysis, the soil samples were air dried, crushed, and made to pass through a 2- mm sieve size before conducting the following physico-chemical fertility indices analyses.

3.7 Laboratory analysis

3.7.1 Soil physical analysis

Bulk density was measured using core method as Grossman and Reinsch (2002) recommended Bulk density

$$BD = Mg/Vt \ \ (g/cm\text{^}3) \qquad \textit{Equation 1}$$

Where M_s = mass of oven dry soil (g)

V_t = Total soil volume (cm^3)which is equivalent to the volume of the cylinder

$$V = \pi r^2 h \qquad \textit{Equation} \qquad 2$$

Where V= volume of core (cm^2) assumed to be equal to soil volume.

Particle Size Distributionwas determined by hydrometer method according to the procedure of Gee and Or (2002) using water and sodium hexametaphosphate (calgon) as dispersant.

Moisture content wasl determined by gravimetric method (Obi, 1990).

Total porosity was computed from the bulk density as described by Vomocil (1965). The calculation is as follows:

$$Tp = 1 - \frac{BD}{PD} x\, 100/1 \qquad \textit{Equation} \qquad 3$$

Where, Tp=Total porosity, BD=Bulk density (g/cm^3), PD=particle density ($2.65g/cm^3$).

3.7.2 Soil chemical analysis

Soil pH was determined in water and 0.1kcl using pH meter in soil/liquid suspension of 1:2.5 (Hendershot, Lalende & Duquette, 1993).

Organic Carbon was determined using the wet oxidation method (Nelson & Sommers, 1996).

Available phosphorus was determined using Bray 2 solution method according to (Olsen & Sommers, 1982). Bray 2 solution was used as an extractant.

Exchangeable K and Na was extracted using 1N neutral ammonium acetate (NH_4OAC) determined using flame photometer (Thomas, 1982).

Exchangeable Magnessium and Calcium were determined using ethylenediaminetetraacetic acid (EDTA) (Thomas, 1982).

Total Nitrogen was determined by kjehdahl digestion method using concentrated H_2SO_4 and a Sodium Copper Sulphate catalyst mixture (Brenner & Yeomans, 1988)

Exchangeable Acidity was determined titrimetrically (Mclean, 1982).

Effective Cation Exchange Capacity (ECEC**)** was calculated from the summation of all exchangeable bases and exchangeable acidity (IITA, 1982).

Percentage Base Saturation (%BS)was determined by computation, this was achieved using the formula;

$$\%BS = \frac{Total\ Exchangeable\ Bases}{ECEC} \ x\, 100/1 \ \textit{Equation} \quad 4$$

Micronutrients (Iron, and Manganese) were determined following the methods described by Udo *et al*., (2009).

Soil Fertility Assessment Using Soil Fertility Ratios

The ratios used include as stated below:

- **i.** Calcium to magnesium ratio (3:1): (Sait, 2015a). The Ca: Mg ratios recommended for sandy soils is 3: 1 and clayey soils is 7:1 (Philips, 2021; Osemwota *et al*., 2007).
- **ii.** Potassium to magnesium ratio (1:1): (Järvan, 2004).
- **iii.** Phosphorus to zinc ratio (10:1): (Essel *et al*., 2021; Philips, 2021).
- **iv.** Iron to manganese ratio (2:1): (Sait, 2015b; Essel *et al*., 2021).

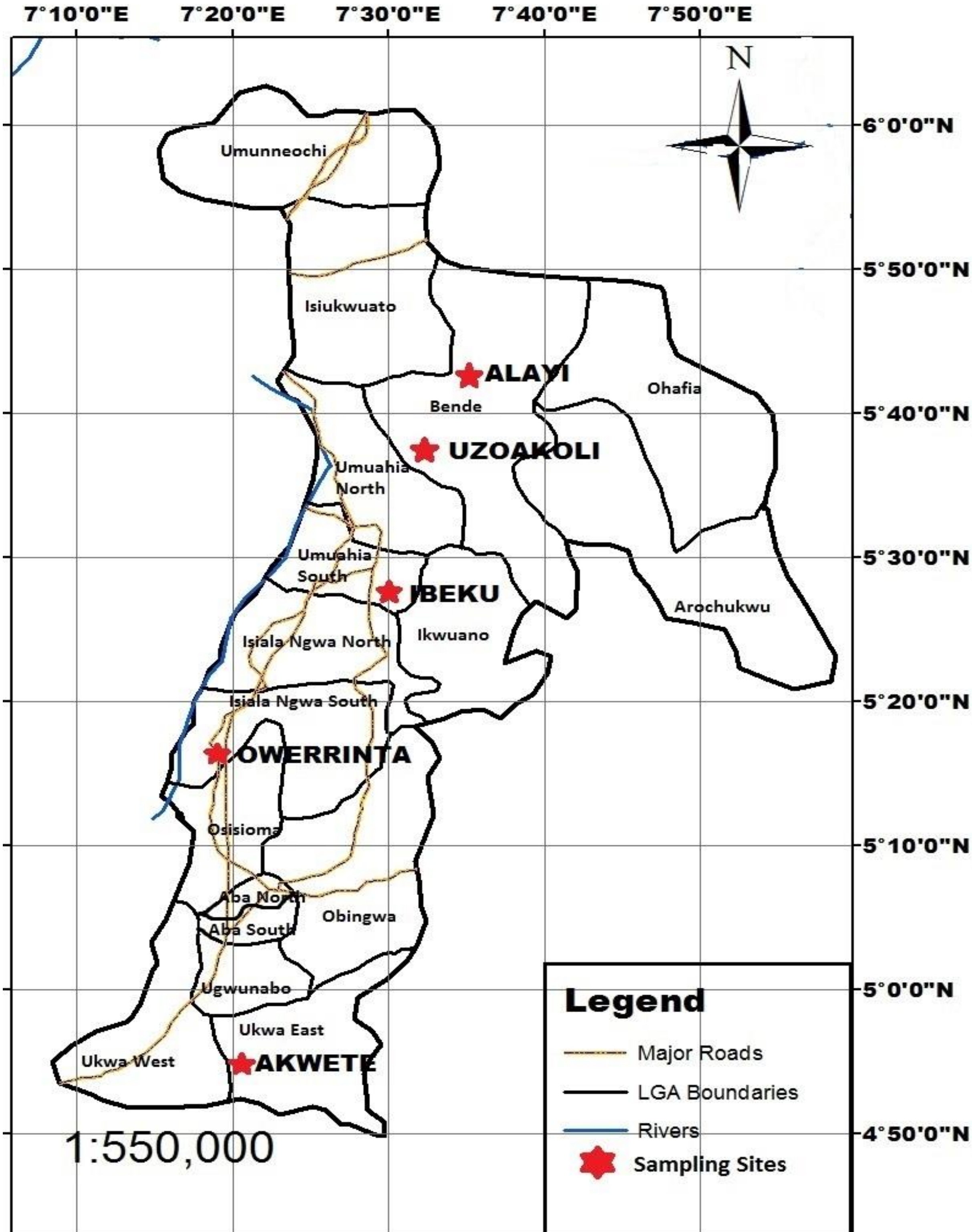

Figure 3.2: Location Map of Abia State Showing the Sample Sites (Modified from open street map)

Morphological properties of soils studied in Abia

Results of the morphological properties of soils of Abia are presented in Table 1. Two master horizons, namely A and B in addition to two transitional horizons AB, BA and BC were identified in soils collected from Akwaette (Profile 01), Alayi(profile 02), Ibeku (Profile 03), Nkporo (Profile 04), Owerrinta (Profile 05) and Uzuakoli (Profile 06). This is typical of tropical soils (Johnson *et al.*, 2005). Besides, it was only Profile 03 and 06 that had argillic subordinate horizonwith evidence of gleying, indicating that there was translocation of clay down the profiles forming argillic horizons (Mulugeta and Sheleme, 2010). Generally, these soils were deep exceeding 100 cm. Accordingly, soil depth (cm) ranged from 0 –170, 0 –200, 0 –174, 0 – 196 and 0 –190 in Profiles 01, 02, 03, 04 and 05. Earlier studies (Raji, 1995; Idoga *et al.*, 2007) attributed extent of soil depth to parent material, erosion and slope of area.

Soil colour varied as very dark gray to brown at surface soils while at the sub-surface horizons it varied from yellowish brown, reddish brown to gray. These colours indicated the release of iron oxides and their occurrence in various hydrated forms due to differences in drainage of the soils (Walia and Rao, 1996). Similar findings were also reported by Arun Kumar *et al.* (2002). According to Nuhu (1983), the brownish tinges in most of the horizons of the profile 02, 04 and 05 might be due to the presence of organic matter which is the main colouring agent in top soil. Moreover, soils profile 03 and 04 were poorly drained as water saturated soils tend to have grey-colored B-horizons (Foth, 1990).

Mottles were identified in endopedons of all these soils except in profile 05. These Mottles varied from red to yellowish colour. Obi *et al.* (2009) attributed mottling to lack of mechanical mixing by plant roots and soil.

Table 1: Morphological properties of soils studied in Abia

Ho	Depth (cm)	Colour (M)	Mottles	TC	Str (S)	Str (G)	Str (F/T)	Con (Wt)	Con (M)	Con (Dry)	Roots	Dra	Bndry
						AKWAETTE(profile 01)							
A	0 – 13	VDG(10YR3/1)	__	S	F	1	gr	Np	vfr	L	Mf-m	WD	C,w
AB	13 - 38	DG(10YR4/1)	__	S	M	1	gr	Np	Vfr	L	Mf-m	WD	C,s
BA	38 - 88	YB(10YR5/4)	__	S	M	2	Sbk	Np	Fr	Sh	Ff	WD	C,s
Bt_1	88 - 135	YB(10YR5/6)	__	SL	M	2	Sbk	Sp	Fr	Sh	Ff	WD	C,s
Bt2	135 - 170	G(10YR6/1)	R(2.5YR4/6)	SL	M	2	Sbk	Sp	Fr	Sh	ff	WD	__
						ALAYI(profile 02)							
A	0 – 15	DB (10YR3/3)	___	S	F	1	sbk	Np	vf	L	Mf-m	WD	C,w
AB	15 – 39	B(7.5YR4/2)	___	LS	f-m	1	Sbk	Np	F	L	Mf-m	WD	C,w
Bt1	39 – 112	LB(7.5YR4/2)	___	LS	f-m	1	Sbk	Np	Fi	Sh	ff-m	WD	C,s
Bt2	112 – 150	LG (5YR7/1)	R(10R 4/6)	SL	m-c	2	Sbk	Sp	Fi	Sh	Ff	WD	C,s
BC	150 - 200	G(5YR6/1)	R(10R 5/6)	LS	C	2	Sbk	Np	Fr	Sh	Ff	WD	__
						IBEKU(profile 03)							
A	0 – 11	VDG(7.5YR3/1)	____	SC	M	2	Ab	Ss	Fr	Sh	cf	WD	C,s
AB	11 – 35	B(7.5YR4/4)	____	C	C	3	Ab	Sp	Fi	H	Ff	PD	C,w
Bg1	35 – 70	RG(5YR5/2)	____	SCL	C	3	Sbk	P	Fi	H	Ff	PD	A,w
Bg2	70 – 109	G(5YR5/1)	Y(10YR7/6)	SCL	C	3	Sbk	P	Fi	Vh	__	PD	C,s
BC	109 - 140	G(5YR6/1)	Y(10YR8/6)	C	C	3	Sbk	P	Fi	Vh	__	PD	__
						NKPORO(profile 04)							
A	0 – 17	DG (7.5YR4/1)	__	SL	f-m	2	Sbk	Ss	Fi	H	Mf-m	PD	C,w
AB	17 – 48	LB (7.5YR6/3)	__	SCL	m-c	2	Sbk	Ss	Fi	H	Cf-m	PD	G,w
Bt1	48 – 99	G(5YR5/1)	R(2.5YR4/6)	SC	C	2	Sbk	Sp	Fi	H	Ff	PD	C,s
Bt2	99 – 125	G(5YR6/1)	R(2.5YR5 /6)	SCL	C	2	Sbk	P	Vfi	Vh	Rr	PD	C,s
Bt3	125 - 174	LG(5YR7/1)	LR(2.5YR6/6)	SC	C	3	Sbk	P	Vfi	Vh	Rr	PD	___
						OWERRINTA(profile 05)							
A	0 – 11	DB(7.5YR3/2)	__	LS	Vf	1	Gr	__	Fr	L	Mf-m	WD	G,w
AB	11 – 31	B(7.5YR4/2)	__	SL	F	1	Gr	Ss	Fr	L	Mf-m	WD	C,s
Bt1	31 – 70	RB(5YR5/3)	__	SL	M	2	Sbk	Ss	Fr	Sh	ff-m	WD	C,s
Bt2	70 -106	RB(2.5YR5/3)	__	SCL	M	2	Sbk	Sp	Fi	Sh	Ff	WD	C,s
Bt3	106-196	R(2.5YR4/6)	__	SL	M	2	sbk	Ss	fr	Sh	rr		__
						UZUAKOLI(profile 06)							
A	0 – 18	VDG(10YR3/1)	R(2.5YR4/6)	SCL	M	2	Cr	Sp	Fr	Sh	Cf-m	PD	A,w
AB	18 – 46	DG (7.5YR4/1)	R(2.5YR4/8)	SCL	M	2	Sbk	Sp	Fi	H	Ff	PD	C,w
Bg1	46 - 116	G(5YR5/1)	R(2.5YR5/6)	SCL	C	3	Sbk	P	Fi	H	Ff	PD	G,s
Bg2	116 - 190	G(5YR6/1)	PR (2.5YR6/2)	SC	C	3	sbk	P	vfi	Vh	__	PD	_---_

Drainage: WD=Well drained, PD= Poorly drained, ID=Imperfectly drained, MWD= Moderately well drained,
Boundary: A=abrupt, C=clear, w=wavy, G=gradual, D=diffuse and s=smooth.
S=Sub-angular, bk, blocky, 1-weak, 2 – moderate, 3 – strong, g – granular, C – structure, V – very, F= fine, g – granular, P – platy

From the *in situ* finger test, soils sand, loamy sand and sandy loam textured in profiles 01, 02 and 05 whereas it was dominated by sandy clay loam in profiles 03, 04 and 06. Sand dominated textural classes encourage movement of soil water, particularly in the surface soils, and such mobility of soil moisture at epipedons might reduce soil water retention makimg soils less suitable for production of most crops (Ofem *et al*., 2022).

The soils had a weak, fine, subangular blocky structure at the epipedon while the subsurface horizons consisted of moderate, medium subangular blocky. The moist consistencies were friable in soils of profile 05, very friable and friable in epipedon and endopedons respectively (profile 01 and 02), very friable and firm (profile 03 and 05), firm and very firm (profile 04) and friable and very firm (profile 06). The very friable and friable consistence observed in the surface soils of most pedons could be attributed to the higher OM contents of the horizons (Mulugeta and Sheleme, 2010).

Presence of roots at the epipedon of Akwaette(profile 01), Alayi(profile 02), Nkporo(profile 04) and Owerrinta(profile 05) was medium, few to many whereas common, few in Ibeku(profile 03) and Uzuakoli(profile 06). At the sub-surfaces it varied from few to rare. The combination of the soil structure and the gravel content also influenced the drainage of the soils which ranged from well drained in soils of profile 01, 02 and 05 and poorly drained in profile 03, 04 and 06. Ibia (2002) reported that poor drainage condition of soils prevents strong weathering and subsequent formation of sesquioxides in the soils. Boundary distinctiveness indicated that soils were clear wavy at the epipedons of profile 01, 02 and 04, clear smooth in profile 03 whereas it was gradual wavy and abrupt in profile 05 and 06, respectively. According to Esu (2010), a boundary form was a result of lateral movement of soils. Moreover the boundary forms of these soils could be as a result of lateral movement and properties of soils and weathering processes or clay lassivage in the soil horizons (Onweremadu *et al*., 2007 and Ahukaemere, 2018).

Fertility indices of soils

Table 2 summarized the results of fertility indices of soils of Abia State. According to Kalala *et al*. (2017), other than the absolute amount, the cations availability to plants is sometimes influenced by several ratios including Ca:Mg, Mg:K and K:TEB. In the present study, results of some selected fertility indices as shown demonstrated low coefficient of variability (CV≤8.15%) for C/N ratio. Distribution of C/N ratio was also irregular with higher values at epipedons of all the soils but Ibeku(profile 03). It varied from 12.05-10.06 (mean=11.05), 12.38-10.38 (mean=11.08), 12.11-10.12 (mean=11.29), 12.33-10.59 (mean=11.64), 12.51-11.86 (mean=12.23) and 12.55-10.45 (mean=11.44) in Akwaette (profile

Table 2: Fertility indices of soils of Abia State

Ho	Depth	C/N	Ca/Mg	K/Mg	Ca+Mg+K+Na/Al+H	ESP	EPP	Al/CEC	Fe/Mn
				AKWAETTE(profile 01)					
A	0 – 13	12.05	2.56	0.49	1.29	22.99	4.02	0.21	3.24
AB	13 – 38	11.87	2.22	0.26	1.01	8.3	3.18	0.28	3.24
BA	38 – 88	10.06	2.54	0.23	1.08	8.33	2.61	0.18	3.13
Bt_1	88 – 135	11.01	2.56	0.13	1.41	8.66	1.73	0.18	3.33
Bt2	135 – 170	10.28	2.95	0.24	1.26	3	3	0.16	3.32
Mean		**11.05**	**2.57**	**0.27**	**1.21**	**10.26**	**2.91**	**0.2**	**3.25**
CV		**8.15**	**10.15**	**49.49**	**13.58**	**73.09**	**28.72**	**24.32**	**2.55**
				ALAYI(profile 02)					
A	0 – 15	12.38	3.03	0.4	0.53	0.52	3.09	0.28	2.88
AB	15 – 39	10.43	3.08	0.58	0.53	0.82	4.11	0.25	2.82
Bt1	39 – 112	10.38	2.84	0.58	0.53	1.22	4.38	0.29	2.82
Bt2	112 – 150	11.54	2.67	0.53	0.65	1.74	4.73	0.24	3.05
BC	150 – 200	10.66	2.68	0.57	0.43	1.8	3.78	0.24	3.00
Mean		**11.08**	**2.86**	**0.53**	**0.53**	**1.22**	**4.02**	**0.26**	**2.92**
CV		**7.81**	**6.75**	**14.32**	**14.39**	**46.12**	**15.5**	**9.96**	**3.59**
				IBEKU(profile 03)					
A	0 – 11	12.11	2.19	0.48	3.34	4.19	9.49	0.06	2.90
AB	11 – 35	10.71	2.34	0.41	2.18	5.3	6.94	0.07	2.54
Bg1	35 – 70	11.41	2.83	0.29	3.91	5.32	5.2	0.08	2.34
Bg2	70 – 109	12.12	2.87	0.31	4.14	5.51	5.62	0.06	2.20
BC	109 – 140	10.12	1.54	0.29	2.79	6.19	6.87	0.05	2.10
Mean		**11.29**	**2.35**	**0.36**	**3.27**	**5.3**	**6.82**	**0.06**	**2.42**

CV		**7.77**	**23.17**	**23.93**	**24.52**	**13.57**	**24.54**	**12.37**	**13.19**
				NKPORO(profile 04)					
A	0 – 17	12.33	1.35	0.47	1.31	0.65	9.31	0.2	2.44
AB	17 – 48	12.08	1.37	0.47	0.87	0.92	7.57	0.26	2.43
Bt1	48 – 99	10.59	1.11	0.53	0.66	1.64	7.69	0.33	0.21
Bt2	99 – 125	11.6	1.12	0.54	0.61	1.65	7.35	0.27	0.19
Bt3	125 – 174	11.6	1.21	0.53	0.52	0.76	6.5	0.27	2.04
Mean		**11.64**	**1.23**	**0.51**	**0.79**	**1.12**	**7.68**	**0.26**	**1.46**
CV		**5.72**	**9.92**	**7.05**	**39.68**	**43.06**	**13.29**	**17.15**	**79.73**
				OWERRINTA(profile 05)					
A	0 – 11	12.51	1.05	0.05	0.64	0.17	1	0.32	2.88
AB	11 – 31	11.86	1.3	0.08	0.6	0.16	1.29	0.3	2.73
Bt1	31 – 70	11.55	2.19	0.08	0.99	0.3	1.2	0.19	2.54
Bt2	70 – 106	12.33	2.43	0.08	0.96	0.37	1.11	0.24	2.52
Bt3	106 -196	12.92	2.21	0.72	0.92	0.26	8.79	0.35	2.48
Mean		**12.23**	**1.84**	**0.2**	**0.82**	**0.25**	**2.68**	**0.28**	**2.63**
CV		**4.41**	**33.5**	**142.5**	**22.71**	**35.52**	**127.6**	**23.29**	**6.349**
				UZUAKOLI(profile 06)					
A	0 – 18	12.55	3.43	0.41	1.04	1.14	4.19	0.15	2.33
AB	18 – 46	10.45	3.7	0.45	1.08	1.17	4.45	0.17	2.27
Bg1	46 – 116	10.91	3.43	0.45	1.16	1.51	4.76	0.14	1.83
Bg2	116 – 190	11.85	3.16	0.45	1.23	1.61	5.17	0.13	1.91
Mean		**11.44**	**3.43**	**0.44**	**1.12**	**1.36**	**4.64**	**0.15**	**2.08**
CV		**8.23**	**6.47**	**4.68**	**7.45**	**17.39**	**9.12**	**10.68**	**12.12**

01), Alayi(profile 02), Ibeku(profile 03), Nkporo(profile 04), Owerrinta(profile 05) and Uzuakoli(profile 06), respectively. The C:N ratio of all the soil but profile 05 fall below the optimal range (10-12:1) acceptable for arable soils (Havlin *et al*., 1999). This could be attributed to high oxidation and loss of organic matter as evidenced by the poor or very low SOC in the two profiles. The C:N ratio is important because the availability of nitrogen (N) for plant growth is dependent on the ratio. High C:N > 30:1 implies N immobilization due to decomposition of organic residue by microbes while C:N < 20:1 implies limited immobilization and release of N into the soil environment for plant uptake (Jones, 2003).

Similarly, soils of Alayi(profile 02), Ibeku(profile 03) and Uzuakoli(profile 06) followed similar pattern with C/N ratio as higher values of Ca/Mg were obtained at the epipedons than endopedons whereas the reverse was the case for other pedons. On average basis, Ca/Mg was higher(3.43) at Uzuakoli(profile 06) followed by Alayi(profile 02) (2.86), Akwaette(profile 01) (2.57), Ibeku(profile 03) (2.35), Owerrinta(profile 05) (1.84) and Nkporo(profile 04) (1.23). The ratio of exchangeable Ca/Mg should not exceed 10/1 to 15/1 to prevent Mg deficiency (Havlin *et al*., 1999). The Ca/Mg ratio of the studied soils was in the range of 1.23 - 3.43 indicating that the response of crops to Mg is not likely. According to Sharu *et al*. (2013), correct Ca: Mg ratio will improve soil structure, reduce leaching of other plant nutrients, reduce weed population and generally improve the balance of most soil nutrients. Moreover, it was irregularly distributed with low CV in all the soil units apart from Ibeku(profile 03) and Owerrinta(profile 05) that had moderate CV (≤33.5%).

Potassium/magnesium ratio was generally lower than C/N and Ca/Mg. It was also distributed irregularly in all the soils but was comparatively higher at the endopedons than epipedons of most soils. However, its coefficient of variability was high in profile 01(CV=49.49%) and 05(CV=142.5%), moderate in profile 03(CV=23.93%) and low (CV≤14.32%) in profile 02, 04 and 06. Furthermore, it varied with soil units with a range of 0.49-0.13, 0.58-0.4, 0.48-0.29, 0.54-0.47, 0.72-0.05 and 0.45-0.41 and mean values of 0.27, 0.53, 0.36, 0.51, 0.2 and 0.44 in profile 01, 02, 03, 04, 05 and 06 respectively, indicating that it was highest in profile 02 than others. The recommended K/Mg are < 5/1 for field crops, 3/1 for vegetables and sugar beets and 2/1 for fruit and greenhouse crops. The K/Mg ratio of the studied soils varied from 0.2 to 0.53 and hence it is within the acceptable range for crop production (Havlin *et al*., 1999).

The Ca+Mg+K+Na/Al+H in Abia State like other fertility indices differed across the sampling sites. It varied from 1.41-1.01 (mean=1.21), 0.65-0.43 (mean=0.53), 4.14-2.79 (mean=3.27), 1.31-0.52 (mean=0.79), 0.99-0.6 (mean=0.82) and 1.23-1.04 (mean=1.12) in profile 01, 02, 03, 04, 05 and 06, respectively. Similarly, Ca+Mg+K+Na/Al+H contents did not follow regular pattern within all the soil profiles with the exception of profile 04 where it decreased regularly with depth. Moreover, it was higher in endopedons of most of the soils with the coefficient of variability being low in soils from Akwaette, Alayi and Uzuakoli, moderate in Ibeku and Owerrinta whereas it was high in Nkporo, indicating that Ca+Mg+K+Na/Al+H were more uniformly distributed in the later than the former. In addition, higher values of Ca+Mg+K+Na/Al+H recorded in profile 03 indicated greater concentration of basic cations than total acidity.

All the soils also had an irregular distribution pattern of exchangeable sodium percentage (ESP) with the exception of profile 02 and 03 that increased and later decreased with depth. Among the sites, a wide coefficient of variation (CV≤73.09%) was recorded in all the soils apart from profile 03(CV=13.57%) and 06(CV=17.39%) which exhibited low and moderate variation respectively, suggesting that ESP was more uniformly distributed in profile 03 than others. However, averaged over soils, there was greater value of ESP in profile 01 (10.26) compared to profile 03(5.3), profile 06(1.36), profile 02(1.22), profile 4 (1.12) and profile 05(0.25). The values of exchangeable sodium percentage (ESP) in all the soils were generally far below 15%, the critical limit for sodicity (Brady and Weil, 2002).

Like most ratios studied, potassium: CEC ratio varied irregularly within the soil depths of all sampled soils. In soil units of Akwaette(profile 01), Alayi(profile 02), Ibeku(profile 03), Nkporo(profile 04) Owerrinta(profile 05) and Uzuakoli(profile 06), it ranged as 4.02-1.73 (mean=2.91), 4.73-3.09 (mean=4.02), 9.49-5.2 (mean=6.82), 9.31-6.5 (mean=7.68), 8.79-1.0 (mean=2.68), 5.17-4.19 (mean=4.64).The EPP was observed to be greater in epipedons of all the soils apart from profile 05 and 06 where higher values were obtained at the endopedons. Results of coefficient of variation showed moderate variation for profile 01, 02 and 03, low variation for profile 04 and 06 and high variation for profile 05.

Aluminium: cation exchange capacity of the soils varied among soil profiles in Abia State as well, showing an irregularly pattern in all the soil depths. It varied from 0.28-0.16, 0.28-0.24, 0.08-0.05, 0.33-0.2, 0.35-0.19, and 0.17-0.13 with mean values of 0.2, 0.26, 0.06, 0.26, 0.28, and 0.15 in profile 01, 02, 03, 04, 05 and 06, respectively, indicating that it was higher in Alayi than others. Distribution pattern of Al/CEC was however moderate (CV=17.15-24.32%) in soils of profile 01, 04 and 05 meanwhile in profile 02, 03 and 06 it was more uniformly distributed with CV 10.68 to 9.96. Higher Al/CEC value implied higher concentration of Al compared to soil CEC. According to Landon (1991), Aluminium ions are released from clay lattices at pH values of about below 5.5 and become exchangeable in the clay complex

All soil profiles exhibited low variation (CV≤15%) with the exception of profile 04 that exhibited high (CV>35%) variation for Fe/Mn, suggesting erratic pattern of distribution of Fe/Mn in profile 04. It was also observed that Fe/Mn ratios were higher at the epipedons of profile 01 and 02 whereas profile 03, 04, 05 and 06 had greater Fe/Mn ratio at the endopedons. In general however, Fe/Mn had a range of 3.24-3.13, 3.05-2.82, 2.90-2.10, 2.44-0.19, 2.88-2.48 and 2.33-1.83 with mean values of 3.25, 2.92, 2.42, 1.46, 2.63 and 2.08 in profile 01, 02, 03, 04, 05 and 06, respectively, implying highest and lowest Fe/Mn ratio in profile 01 and profile 04, respectively. According to Malvi (2011), the pre-determined ratio of Fe: Mn is 2:1. Therefore, from the results, only profile 04 had Fe: Mn within this range. Microelements Fe and Mn are antagonistic and one will inhibit the uptake of the other, implying the higher the Fe, the lower Mn concentration.

CONCLUSION

Fertility status of soils varied as shown in differences among elemental ratios. Soils were generally of low fertility using Ca/Mg ratio except soils from Uzuakoli.There were low variations in Fe/Mn ratios in all soils except soils formed over shale at Nkporo.

REFERENCES

Ahukaemere, C.M. (2018). Suitability Evaluation of Some Soils of Southeastern Nigeria for Oil Palm (Elaeis guineensis) and Cocoa (*Theobroma Cacao*) Cultivation. *Int. Jour. Of Agric. and Rural Dev. Volume 21 (1): 3355-3361.*

Brady, N.C. & Weil, R.R. (2002).*The Nature and Properties of Soils.*13th edition.Macmillan Publishing Co., Upper Saddle River, New Jersey. 905pp.

Bremner, J. M. & Mulvaney, C. S. (1982).Total nitrogen.*In:* Page *et al* (eds). Methods of soil analysis.Part 2. (2nd ed., pp 9:895-926). *Agronomy Monograph*, ASA and SSSA, Madison, Wisconsin

Bremner, J.R & Yeomans, J.C. (1988). Laboratory Techniques In J.R. Wilson (ed) Advances in Nitrogen Cycling in Agricultural Ecosystem C.A.B int. Willing England.

Essel, B, Abaidoo, RC, Opoku, A, Ewusi-Mensah, N. (2021).Mechanisms underlying nutrient interaction of compost and mineral fertilizer application in maize (Zea mays L.) cropping system in Ghana. Frontiers in Soil Science 1:630851 DOI 10.3389/fsoil.2021.630851.

Esu, I.E. (2010). Soil Characterization, Classification and Survey. *Principles of Soil Classification.* (9):119-156.HEBN Publishers Plc, Ibadan. ISBN 978 978 081 373 4.

FAO (2006).World reference base for soil resources.A frame work for international classification, correlation and communication. World Soil Reports (103), FAO, Rome.

Foth, H.D. (1990). *Fundamentals of Soil Science*. 12th edition. John Willey and Sons .New York. Grunwald.ifas.ufl.edu/Nat_resources/organic_matter/ organic.htm (Accessed on 02/08/2009).

Gee, G.W. &Or, D., (2002). Particle size distribution: In: Dane, J.H. and G.C. Topps. (ed.). Methods of soil analysis, Part 4, Physical Methods (Pp: 225-293). Soil Science Society of America Book Series, No. 5.SSSA, Madison, Wisconsin.

Gogo, S, & Pearce, D M E. (2009). Carbon, cations and CEC: interactions and effects on microbial activity in peat. Geoderma, 153(1–2): 76–86.

Grossman, R.B. & Reinsch, T.G. (2002) Bulk Density and Linear Tensibility. In: J.H. and Topps, G.C. (Eds.), Methods of Soil Analysis, Part 4. Physical Methods (pp: 201-228), Soil Science Society American Book Series No.5. ASA and SSSA, Madison Wisconsin.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL (1999). Soil fertility and fertilizers. Prentice Hall, New Jersely. pp. 345-355.

Havlin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson. (2004). *Soil fertility and fertilizers, An introduction to nutrientmanagement*. Singapore: Pearson Education.

Hendershot, W.H, Lalende .H & Duquette.M (1993) Soil reaction and exchangeable acidity in sampling and methods of Soil Science, Lewis productions, London Pp 142-145.

Järvan, M. (2004). Available plant nutrients in growth substrate depending on various lime materials used for neutralizing bog peat. *Agronomy Research* 2(1):29_37.

Ibia TO (2002). Forms of Fe and Al in soil profiles of inland flood plains of South Eastern Nigeria. Nig. J. Soil Res. *3*:72-77.

IITA (International Institute of Tropical Agriculture) (1982).Automated and semi-automated methods for soil and plant analysis. In: Tel, D.A and Raoleds, P.V manual series 7.

Idoga, S and Azagaku, D.E. (2005). Characterization and classification of soils of Janta area, Plateau State of Nigeria. J. of Soil Sci. 15:116-122.

Idoga, S., Ibanga, I.J. and Malgwi, W.B. (2007). Variation in soil morphological and physical properties and their management implication on a toposequence in Samaru area, Nigeria. In Uyovbisere, E.O., Raji, B.A., Yusuf, A.A., Ogunwale, J.O., Aliyu, L. and Ojeniyi, S.O. (ed).(2007). *Soil and Water Management for Poverty Alleviation and Sustainable Environment.* Proceedings of the 31th Annual Conference of the Soil Science Society of Nigeria held at Ahmadu Bello University Zaria, Nigeria. Nov. 13-17, 2006. pp 19-26.

Johnson, J.M.F., Allmaras, R.R., & Reicosky, D.C. (2007).Estimating source C from crop residues, roots and rhizodeposits using the national grain-yield database.Agronomy Journal. 98:622-636

Jones J (2003). Agronomic Handbook: management of crops, soils, and their fertility. CRC Press, Boca Raton, Florida, USA. P. 482.

Kalala, A. M., Msanya, B. M., Amuri, N. A., & Semoka, J. M. (2017). Pedological characterization of some typical alluvial soils of Kilombero District, Tanzania.

Landon, J., (1991). Booker tropical soil manual: A Handbook for soil survey and agricultural land evaluation in the tropics and subtropics. John Wiley & Sons Inc., New York. 474p.

Malvi, U. R. (2011). Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka Journal of Agricultural Sciences*, *24*(1).

Mclean, E.V. (1982). Aluminum. In page, A. L., Miller, R. H., Keeney, D. R., (eds). Methods of soil analysis, part 2, Am. Soc. Agron Madison WL. 978 – 998.

Moraetis, D, Papagiannidou, S. Pratikakis, A. Pentari, D., & Komnitsas, K. (2016). Effect of zeolite application on potassium release in sandy soils amended with municipal compost. *Desalination and Water Treatment, 57(*28):13273-13284.https://doi.org/10.1080/19443994.2015.1065440.

Mulugeta, D., & Sheleme, B. (2010). Characterization and classification of soils along the toposequence of Kindo Koye Watershed in

Southern Ethiopia. *East African Journal of Sciences*, *4*(2), 65-77.

Munsell Color Company, (1994). Munsell soil color charts. Revised edition, Macbeth Division of Kollmorgen, New Windsor, NY.

Nelson, D. W. and Sommers, L. E. (1982).Total carbon, Organic carbon and organic matter. In: Page, A. L., Miller, R. H. and Keeney, D. R. (eds.) Methods of soil analysis. Part 2.American Society of Agronomy. Madison WIS.Pp 539-599.

NEWMAP. (2017). "Environmental and Social Management Plan (ESMP) of Umuda Isingwu/Umuagu - Ibeku Gully Erosion Complex in Umuahia North Local Government of Abia State." Draft Final Report, 2017.

Obi, M.E. (1990): Soil physics: A compendium of lectures, University of Nigeria Nsukka. pp: 103.

Obidike-Ugwu, E. O., Ogunwole, J. O., Odunze, A. C., Nwafor, O. E. and Ariwaodo, J. O. (2022). Application of Semivariogram model to quantify spatial variability of soil properties in a forested tropical soil. *Nigeria Journal of Soil Science* Vol. 32(1): Pp 117-123

Ofem K.I., Kefas P.K. and Garjila Y.A. (2022). Land suitability evaluation for oil palm production in Cross River State, Nigeria. *Agro-Science*, **21 (3),** 85-93. https://dx.doi.org/10.4314/as.v21i3.10

Olsen, S. R. & Sommers, L.E. (1982). Phosphorus In: Methods of soil analysis, part 2 (eds. Page, A. L., Miller, R. H., Keeney, D. R.) American Society of Agronomy Madison Wisconsin pp 15 – 72.

Onweremadu, E. U., (2007). Pedogenic calcium loss and uptake of calcium by Gmelina growing in an Isohyperthermic Kandiudult. J. Plant Sci, 2:625-629.

Onweremadu, E.U, B. Ndukwu; C .C. Opara, V.N. Onyia., (2007). Characterization of Wetland Soils of Zamara, Bayelsa state, Nigeria in relation to Iron and Manganese distribution. *Int. J. of Agric. and Food Sys*, 1(1): 80-86.

Onweremadu,E.U.,A.Wenibo,,S.I.Ihim,A.U.Onyechere and C,C,Eze(2024).Leaching of soils of central Southeastern Nigeria.UAES J.Innov. Sci.& Technol. for Dev.1(1):79-87.

Onyechere A.U., Onweremadu E. U., Aririguzo B. N. and Ahukaemere C. M (2023) Geospatial Distribution of Soil Reaction in Central Southeastern Nigeria. *Nigerian Journal of Soil Science*. Vol. 32 (2). Pp 111-116. DOI: https://doi.org/10.36265/njss.2023.320215

Onyechere A.U., Ukabiala M. E., Amanze C. T., Onyechere I. C (2023a). Application of GIS in the Study of Spatial Variability of Selected Soil Properties in Southeastern Nigeria. ASRIC Journal on Agricultural Sciences Vol.4(1). Pp 60-71

Osemwota, I.O, Omueti, J.A, Ogboghodo, A.I. (2007). Effect of calcium/magnesium ratio in soil on magnesium availability, yield, and yield components of maize.

Philips, L. (2021). Managing soil mineral ratios. Farmer's Weekly. Available at https://www.farmersweekly.co.za/crops/field-crops/managing-soil-mineral-ratios (accessed on 22 July 2021).

Raji, B. A. (1995). *Pedogenesis of ancient dune soils in the Sokoto sedimentary basin, North Western Nigeria,* unpublished. Ph.D thesis ABU Zaria, Nigeria. pp 194.

Reinsch, T.G., R.B.Grossman, (1995). A method to predict bulk density of tilled Ap horizons. Soil & Tillage Research, 34:95-104.

Sait, G. (2015a). Six secrets to soil test success (Part 1). Nutrition Matters.Available at http://blog.nutri-tech.com.au/six-secrets-to-soil-test-success-1/ (accessed on 13 May 2022).

Sait, G. (2015b). Six secrets to soil test success (Part 2). Nutrition Matters.Available at http://blog.nutri-tech.com.au/six-secrets-to-soil-test-success-2/ (accessed on 14 May 2022).

Sanchez, P. Palm,C., & Buol, S. (2003). Fertility capability soil classification: A tool to help assess soil quality in the tropics. *Geoderma*, 114:157-185. DOI: 10.1016/S0016-7061(03)00040-5.

Sanchez, P. A., Ahamed, S., Carré, F., Hartemink, A.E., Hempel, J., Huising, J., Lagacherie, P., McBratney, A.B., McKenzie, N.J., Mendonça-Santos, M.L., Minasny, B., Montanarella, L., Okoth, P., Palm, C.A, Sachs, J.D., Shepherd, K.D., Vågen, T.G., Vanlauwe, B., Walsh, M.G., & Winowiecki, L. A. (2009). Digital soil map of the world.*Science*, 325:680.

Sharu, M.B., Yakubu, M., Noma, S.S. and Tsafe, A.I. (2013). Characterization and classification of soils on an agricultural landscape in Dingyadi District, Sokoto State, Nigeria. *Nigerian Journal of Basic Applied Science* 21: 137-147.

Soil Survey Staff (2014).*Keys to Soil Taxonomy*.12th Edition.United States Department of

Agriculture, Natural Resources Conservation Service. 72pp.

Van Wambeke A (1989). Tropical soil and soil classification updates. Adv. Soil Sci. New York. 10:176-193.

Vomocil, J.A. (1965). Porosity.In : Black, C.A. (ed.).Methods of soil analysis, part 1. America Society of Agronomy., 9 : 299 – 314.

Walia, C. S., & Rao, Y. S. (1996). Genesis, characteristics and taxonomic classification of some red soils in Bundelkhand region of Uttar Pradesh. *Journal of the Indian Society of Soil Science*, *44*(3), 476-481.

Wilding, L.P., Bouma, J. & Boss, D.W. (1994).Impact of spatial variability on interpretative modeling. In: Quantitative modeling of soil forming processes. Bryant, R.B. and Amold, R.W. SSSA Special publication. No.39: 6175.