

CHARACTERIZATION OF SOILS OF DIFFERENT LITHOLOGICAL FORMATIONS FOR SUSTAINABLE MANAGEMENT IN BENDE LGA, ABIA STATE, NIGERIA

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ABSTRACT

The soils of Bende LGA on diverse lithological formations were characterized, classified and management strategies recommended for their enhanced productivity. A free soil survey delineated the soils of the study area into seven (7) mapping units on the basis of soil homogeneity. They include: Bende AsataNkporo/Ezeaku shale (BDAES), Bende Imo shale group (BDISG), Bende Ameki Formation (BDAF), Bende false bedded sandstone (BDFBS), Bende Upper coal measures (BDUCM), Bende lower coal measure (BDLCM) and Bende Aluvium (BDALM). Twelve (12) pedons namely OW01- OW12 were dug, described and sampled following FAO (2014) guidelines. Samples were collected, prepared and analysed in the laboratory using standard techniques. The results revealed that percentage sand dominated in the particle size analysis followed by clay and silt. The soils were generally acidic with pH (4.20 – 6.50). Total N (0.02 – 0.21 %) and Exchangeable K (0.08 – 1.08 cmolkg⁻¹) were low. Available P of the soils were generally moderate (9.20 – 28.5 mgkg⁻¹). In all the soils, exchangeable cations were low to moderate for calcium (0.10 – 8.80 cmolkg⁻¹), Magnesium (0.60 – 3.80 cmolkg⁻¹) and Sodium (0.006 – 0.38 cmolkg⁻¹). The soil Order identified in the area were Alfisols and Ultisols according to USDA and correlated to Luvisols and Acrisols of WRB. Provision for additional nutrient to boost their fertility status is imperative. Management procedures include application of organic (Poultry dropping, compost etc.), inorganic manure (NPK 15:15:15, single super phosphate etc.) and lime to help boost the soil fertility status and enhance the availability of essential nutrients for crop production in the study area.

Key words: Characterization, classification, management, lithology

INTRODUCTION

Potential use and management of soils differ significantly from one location to the other owing to differences in their composition and characteristics. Afuet *al.* (2017) stated that soil variation is a gradual change in soil properties as a function of landforms, geomorphic elements, soil forming factors and soil management. Obi and Udoh (2011) reported that the majority of the variation in soil properties is as a result of soil formation. Soil formation in a region occurs within a certain period of time depending on the parent material, climate, topography and vegetation of the region (Obi, 2015). Nwaoba *et al.* (2021) noted that different parent materials affect the morphology and chemistry of soils under the same conditions, such as topography and vegetation particularly in the tropics and that variations in soils could arise as a result of parent materials which imply that different soil lithologies give rise to different soil formations. It is therefore necessary to

understand the nature, behaviour and distribution of soils and the parent materials that originated from the soils through characterization and classification of the soils. Akpan-Idioket *al.* (2013) posited that characterization of soils of different parent materials help to determine the nature of the soil materials in terms of genesis, morphological, physical, chemical, nutrient and mineralogical properties. Akamigbo and Asadu (2015), reported that soil characterization is a major criterion for understanding and classifying the soil in order to acquire the best knowledge about the environment. Esu, (2004) enumerated the purposes of soil classification to include organising knowledge related to soils of the world, a region or a locality, to understand relationships among soil individuals being classified and possibly learn new ones. Other reasons are to more easily remember properties of the soils being classified, to establish groups of the soils being classified

for specific land uses. Classification of soils also enhances international communication and agro technology transfer. Therefore, the objectives of this study were to characterize and classify the soils according to USDA soil taxonomy and World Reference Base (WRB) and to recommend appropriate management practices for soils of the area.

MATERIALS AND METHODS

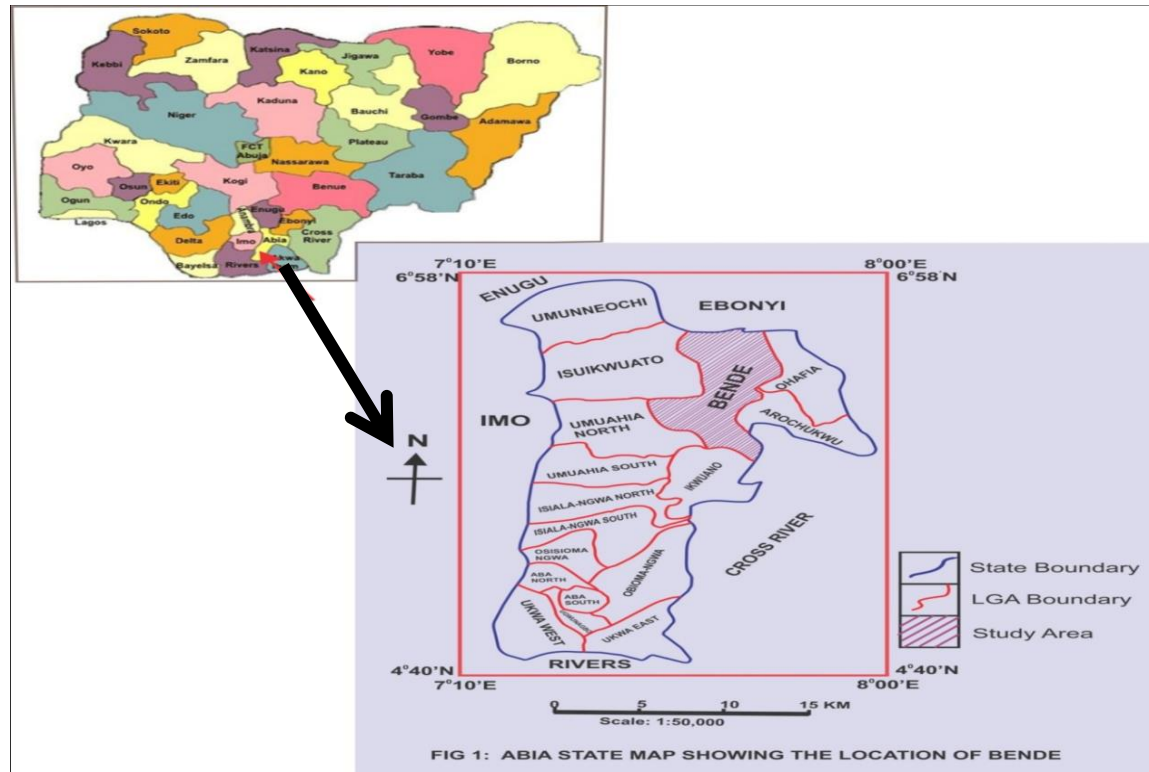


Fig. 1: Map of Nigeria showing the location of Bende Local Government Area
Source: Abia GIS (2020)

Geology- The geology of Bende is shown in Figure 2. The most important geological formations of the study area are the Sandstones (Ameki formation) and Imo Shale. Orajaka (1975) described the lithologic composition of these geologic materials; the shales comprise mudstone, sandstone, limestone, well bedded shale and False bedded sandstones comprise friable poorly sorted coarse grains. The

DESCRIPTION OF STUDY AREA

The study covered the entire Bende Local Government Area (LGA), Abia state, Nigeria (Fig. 1). It is geographically situated between latitudes 5°34' N – 5°56' N and longitudes 7° 38' E – 7° 63' E. Bende LGA, is made up of twelve towns namely; Ezeukwu, Ugwueke, Nkpa, Uzuakoli, Ozuitem, Alayi, Umeimenyi, Mbauzo, Akoli-Imenyi, Igbera, Item and Bende.

Ameki formation consists of medium to coarse grained white sandstone, bluish calcareous silt with mottled clays and thin limestone (Chidera, 2017). Considerable lateral variation in lithology has been observed in many areas. The lower part of the formation consists of fine to coarse grained lenses of sandstones with abundant calcareous shales and thin shaly limestone.

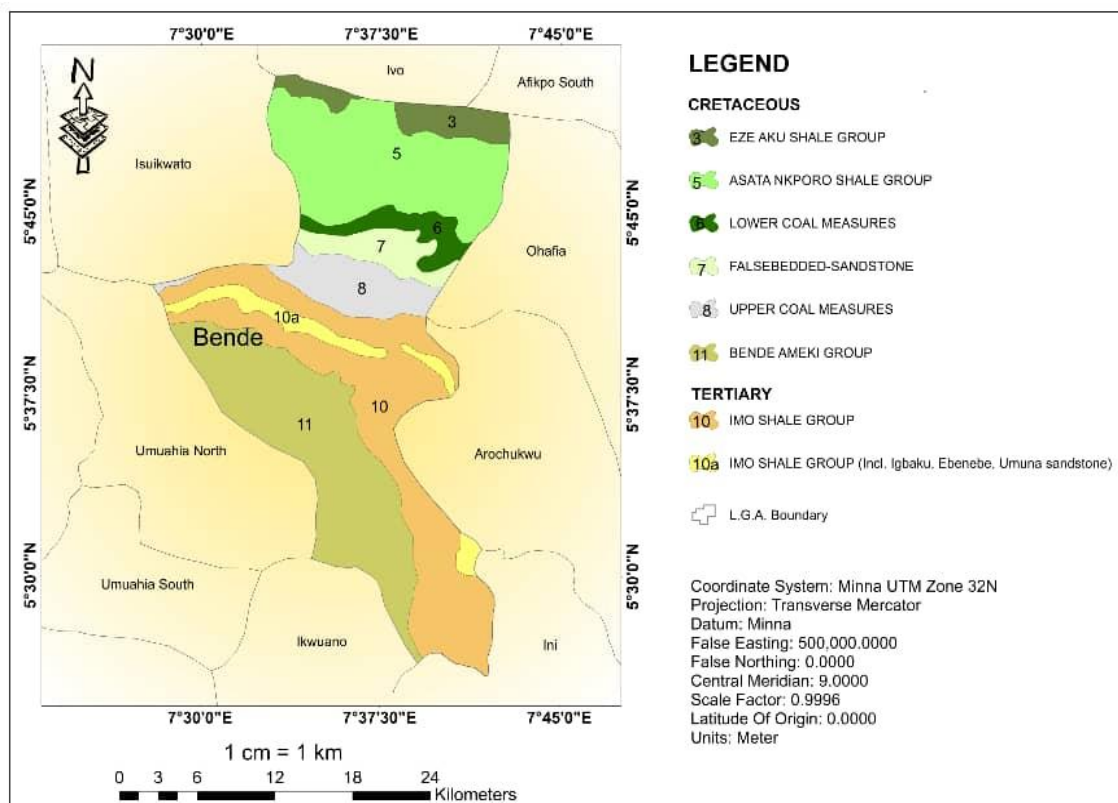


Figure 2: Geologic map of Bende LGA. Source: Abia GIS (2020)

Climate

Bende is a humid zone with a tropical rainforest climate. It exhibits two major seasons, (rainy and dry season), harmattan is a minor season. The total rainfall decreases from 2200 mm in the south to 1900 mm in the north. In general, the entire state is under an udic moisture regime. The mean annual temperature range is between 26°C and 28°C. Mean daily maximum temperature is scarcely below 27°C while the mean daily minimum rarely falls below 18°C (Table 3.1). The relative humidity ranges between 60 and 80 %. Average monthly evapotranspiration also remain low during the rainy season with an average of 0.1 mm/day during the dry season. (NIMET, 2017).

Vegetation and land use: The vegetation of the study area is essentially secondary forest (Otiet *al.*, 2013). The grasses found in the study area are spear grass (*Imperatacylindrica*), guiness grass (*Panicum maximum*), elephant grass (*Pennisetumpurperum*). Arable crops include Rice (*Oryza sativa*) and Cassava

(*Manihotesculenta*), Yam (*Dioscorea spp.*), Maize (*Zea mays*), Cocoyam (*Colocasiaesculentus*). Also, cashew (*Anacardiumoccidentale*) trees, Palm trees, Native pear (*Dacryodesedulis*), mango (*Magniferaindica*), orange, grape fruit and lemon etc. (*Citrus spp.*) are grown.

Field study

The field study involved a reconnaissance visit to the LGA to get preliminary information about the area. Free survey method was used. Auger sampling was done across the LGA at three depths (0 – 15, 15 – 30 and 30 – 45 cm) and described in terms of texture, colour, consistency used to delineate seven (7) mapping units. They include; Bende AsataNkporo/Ezeaku shale (BDAES), Bende Imo shale group (BDISG), Bende Ameki Formation (BDAF), Bende false bedded sandstone (BDFBS), Bende Upper coal measures (BDUCM), Bende lower coal measure (BDLCM) and Bende Aluvium (BDALM). Pedons were dug to study the mapping units in detail. Twelve (12) pedons namely OW01- OW12 were dug, described and sampled following

FAO (2014) guidelines. Towns in Bende LGA that fell in these mapping units include- Ugwueke, Ezeukwu and ElugwuAkanu for BDAES; AkoliImeriyi and Uzuakolifor BDISG, Nkpa and Okporoenyi for BDBAF, Alayi for BDFBS, Item for BDUCM and AhabaImeriyi for BDLCM, Onuiyam and Amaeze for BDALM (Fig 3). Each profile pit was demarcated into horizons and

described for morphological attributes (Soil Survey Staff, 2014). Disturbed and undisturbed (core) soil samples were collected from identified horizons and analyzed for their physical and chemical properties. All sample points (boundary and profile) were geo-referenced using a hand-held (Garmin Etrex) Global Positioning System (GPS) receiver and their coordinates generated for geospatial analysis.

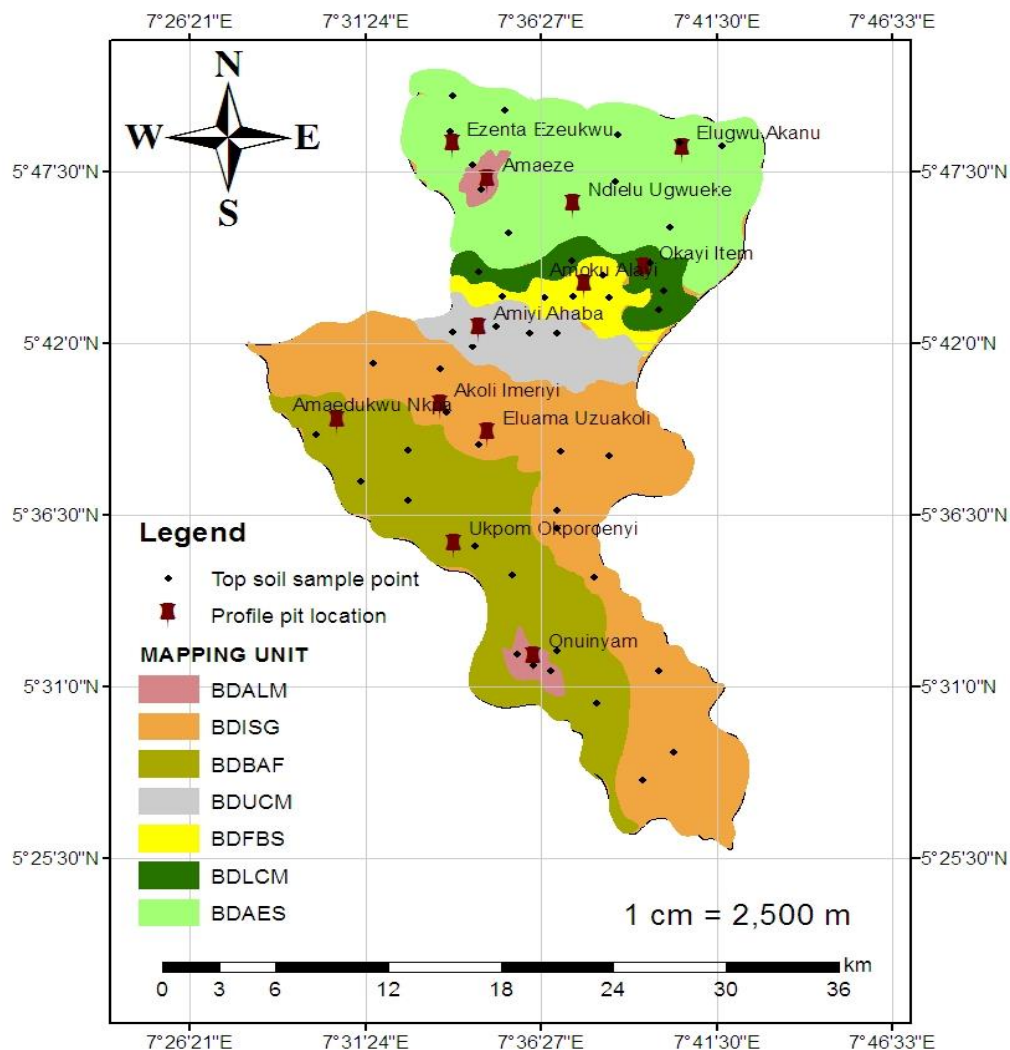


Fig 3: Map of the study area (Bende LGA) showing sampling points

Soil Analysis and Data Interpretation

The disturbed soil samples collected were air-dried under laboratory conditions and sieved through a-2 mm wire mesh sieve. The fine earth fractions (< 2 mm) were subjected to routine soil

analyses using standard procedures described by Udo *et al.*, (2009) & Esu (2004): Particle size distribution was determined by Bouyocous method using sodium hexametaphosphate as dispersant

and selenium tablets as catalysts (Gee and Or 2002).

Undisturbed soil core samples were oven-dried at 105°C to a constant weight and bulk density was calculated using the formulae:

$$bd = m \div v \dots\dots\dots 1$$

Where: bd = bulk density (gcm^{-3}), m = mass of oven dry soil (g), v = volume of core sampler $\{v = \pi r^2 h\}$ {where r and h are radius (m^2) and height (m) of the core sampler}.

Total porosity was computed as:

$$\dots\dots\dots 2$$

Where: Tp = total porosity, Bd = bulk density, Pd = particle density assumed to be 2.65 mgm^{-3} for tropical soils.

Soil pH was measured potentiometrically in a soil: water suspension (ratio 1:2.5) using a glass electrode pH meter (Thomas, 1996). Organic carbon was determined (from the soil passed through 0.5 mm sieves) by the dichromate wet oxidation method (Udo, *et al.*, 2009). Total nitrogen was determined on soil (through 0.5 mm sieve) by the regular micro-Kjeldahl method described by Bremner (1996). Available phosphorus was extracted with Bray number II solution of HF and HCl and the P in the extract was determined spectrophotometrically. The cation exchange capacity (CEC) was determined by the summation method (buffered at pH 8.2) in which all exchangeable cations including exchange acidity (Al^{3+} and H^+). The exchangeable bases were extracted by saturating the soil with neutral 1N KCl. Ca^{2+} , Mg^{2+} , Na^+ and K^+ displaced by NH_4^+ were measured by Atomic Absorption Spectrometer (AAS) (Udo, *et al.*, 2009). Exchangeable acidity was extracted with 1N KCl and estimated in the extract by titration (Udo, *et al.*, 2009).

$$\text{ECEC} = \text{Exchangeable acidity} + \text{Total exchangeable bases (TEB)} \dots\dots\dots 3$$

Base saturation was obtained by expressing the sum of exchangeable bases (Ca^{2+} , Mg^{2+} , Na^+ , and K^+) as percentages of the effective cation exchange capacity:

$$\dots\dots\dots 4$$

Data were interpreted based on Chudeet *al.* (2011) and Enwezoret *al.* (1989). Based on the results obtained from the laboratory analyses and field morphological properties, the soils were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2014) guidelines and side by side correlation

with World Reference Base (WRB). The soils were described in particular order based on the type of diagnostic horizons identified in the pedons. The presence or absence of properties associated with wetness and soils with common similarities (i.e. in kind), arrangement and degree of expression of horizons. Soils were placed in a particular class based on whether they represent the central concepts of group, intergrades or transitional forms.

RESULTS AND DISCUSSION

Morphological and Physical Properties

The summary of the morphological and physical properties of the soils are presented in Tables 1 and 2. The topography of the soils is nearly level plains (0-2%) and gently sloping (2-4 %). The soils were deep (> 100cm) except mapping unit BDALM that was moderately deep (75 cm) and well drained except mapping units BDAES, BDFBS and BDALM with moderate and poor drainage respectively. Results of the particle size analysis showed that sand particles dominated (36.0 – 87.0 %) decreasing down the profiles followed by clay particles (7.0 – 54.0 %) increasing down the profiles and silt fraction (8.0 – 20.0 %) with irregular distribution pattern in all the soil units. This could be attributed to lithology or other anthropogenic influences (Nwaoba *et al.*, 2021; Akamigbo and Asadu, 2015). Soil textures of mapping units BDAES, BDFBS were sandy loam to clay, BDISG, BDAF and BDLCM (loamy sand to sandy clay loam) while BDUCM and BDALM had sandy loam to sandy clay loam at the surface and subsurface soils. Bulk density of the soils ranged from ($1.02 - 1.73 \text{ gcm}^{-3}$). They were less than the critical limit for root penetration (1.85 gcm^{-3}) except for mapping units BDAES and BDFBS with values $1.40 - 2.06 \text{ gcm}^{-3}$ slightly above the critical limit at the subsurface soils and this could be as a result of the clayey texture and low organic matter content of the subsoil horizons (Soil Survey Staff, 2014). The bulk density increased with the soil depths while total porosity ($22.26 - 61.50 \text{ gcm}^{-3}$) of the soils decreased with the soil depths.

Table1: Summary of Morphological Properties of the Soil Units

Horizon Designation	Depth (cm)	Colour (moist)	Mottles	Structure	Wet	Consistence moist	Dry	Boundary
Mapping unit BDAES								
(OW1) Ap	0-24	10 YR 4/4 (DRB)	Absent	3,m,sbk	s-p	fm	h	dw
AB	24-53	10 YR 4/3 (DB)	Absent	3,m,sbk	ss-sp	fm	vh	dw
Btg	53-85	7.5YR 5/4 (B)	7.5YR 6/4 cmd; RY	3,f,sbk	vs-vp	fm	eh	dw
BCg	85-150	10 YR 7/8 (Y)	10YR 6/8 cff; BY	3,f,sbk	vs-vp	vfm	eh	—
(OW 2) Ap	0-21	10 YR 4/4 (DRB)	Absent	3,m,sbk	s-p	fm	h	gw
ABg	21-48	5 YR 4/4 (RB)	5YR 6/4 cmd; RY	3,m,sbk	vs-vp	vfm	vh	gw
Btg	48-95	5 YR 5/6 (YR)	5YR 6/6 fff; RY	3,m,sbk	vs-vp	vfm	vh	dw
BCg	93-165	2.5 YR 4/8 (R)	2.5 YR 4/8 ffd; RY	3,m,sbk	vs-vp	vfm	vh	—
(OW 3) AP	0-20	10 YR 4/4 (DRB)	Absent	3,m,sbk	s-p	fm	h	dw
AB	20-51	5 YR 5/3 (RB)	Absent	3,m,sbk	s-p	fm	h	dw
Bt1	51-96	5 YR 5/6 (RY)	Absent	3,f,sbk	s-p	vfm	vh	cs
Bt2g	96-130	10 YR 7/8 (Y)	7.5YR 5/6 fff; RY	3,f,sbk	vs-vp	vfm	vh	dw
BCg	130-160	7.5 YR 6/4 (LB)	10YR 6/4 fmf; PB	3,m,sbk	vs-vp	vfm	eh	—
Mapping unit BDISG								
(OW 4) Ap	0-23	5YR4/6(YR)	Absent	1,m,sbk	ns-np	fr	s	dw
AB	23-61	2.5YR5/6(RB)	Absent	1,m,sbk	ns-np	fr	s	dw
Bt	61-115	10R6/4(R)	Absent	2,m,sbk	ss-np	fr	h	cw
BC	115-180	2.5YR5/6(R)	Absent	2,m,sbk	ss-np	fr	h	—
(OW 5) Ap	0-20	5YR3/2(DRB)	Absent	1,m,sbk	ns-np	fr	l	dw
AB	20-50	2.5YR3/4(DRB)	Absent	1,m,sbk	ns-np	fr	s	dw
Bt1	50-85	2.5YR4/6(R)	Absent	2,m,sbk	ns-np	fr	s	dw
Bt2	85-140	2.5YR4/8(R)	Absent	2,m,sbk	ss-sp	fr	h	dw
BC	140-200	2.5YR4/6(R)	Absent	2,m,sbk	s-p	fr	h	—
Mapping unit BDAF								
(OW 6)Ap	0-25	5YR2/1(BI)	Absent	2,m,sbk	ns	fr	s	gw
AB	25-61	5YR3/3(DRB)	Absent	2,m,sbk	ss	fr	sh	gw
B	61-115	5YR4/3(RB)	Absent	3,m,sbk	ss	fr	h	dw
BC	115-170	5YR4/6(YR)	Absent	3,m,sbk	ss	fm	h	—
(OW 7) Ap	0-25	7.5YR6/4(LB)	Absent	1,c,gr	ns	vfr	l	cw
AB	25-75	10YR6/4(LYB)	Absent	1,c,gr	ns	fr	l	cw
Btg1	75-120	10YR7/3(VPB)	7.5YR6/6cfd;RY	2,m,g	ns	fr	s	gw
Btg2	120-180	7.5YR7/6(RB)	7.5YR5/6cmd;SB	2,m,sbk	ss	fr	s	gw
Mapping unit BDFBS								
(OW8) Ap	0-20	10YR3/2(DRB)	Absent	2,c,sbk	s	fr	h	dw
AB	20-65	7.5YR5/3(B)	Absent	2,c,abk	s	fm	h	dw
Bt	65-97	7.5YR6/6(RY)	Absent	2,f,sbk	vs-vp	vfm	vh	dw
Btg	97-135	7.5YR5/8(SB)	7.5YR6/6cfd;RY	3,m,sbk	vs-vp	vfm	vh	dw
BCg	135-180	7.5YR6/4(LB)	7.5YR5/6cmd;SB	2,f,abk	vs-vp	vfm	vh	—
Mapping unit BDLCM and BDUCM								
(OW 9) Ap	0-23	5 YR 2/1 (BI)	Absent	1,c,gr	ns	vfr	s	dw
AB	23-55	2.5 YR 3/3 (DRB)	Absent	1,c,gr	ns	vfr	s	dw
Bt1	55-105	2.5 YR 4/6 (R)	Absent	1,c,gr	ns	vfr	sh	dw
Bt2	105-140	2.5 YR 5/6 (R)	Absent	1,m,sbk	ns	vfr	sh	dw
BC	140-180	2.5 YR 5/6 (R)	Absent	1,m,sbk	ss	fr	sh	—
(OW 10)Ap	0-30	2.5 YR 3/3 (DRB)	Absent	1,m,gr	ns	fr	s	dw
AB	30-75	5 YR 3/6 (DRB)	Absent	2,m,sbk	ss	vfr	sh	dw
Bt	75-135	5 YR 5/8 (BRB)	Absent	2,m,sbk	ss	vfr	sh	dw
BC	135-180	5YR 4/8 (RB)	Absent	2,m,sbk	ss	vfr	sh	—
Mapping unit BDALM								
(OW 11)Apg	0-24	10YR 6/3(PB)	10YR 6/3;cff;PB	2,m,sbk	ss	fm	sh	dw
ABg	24-40	10YR 7/4(VPB)	10YR 6/2cmd;PB	2,m,sbk	ss	fm	sh	gw
BCg	40-75	2.5YR 4/4(B)	2.5YR 5/6cmd;RB	2,m,sbk	vs	fm	h	—
(OW 12)Apg	0-15	10YR 8/4(VPB)	10YR 8/6fff;Y	2,m,sbk	ss	fm	sh	cw
Btg	15-36	10YR 7/3(LG)	10YR 6/3fmd;PB	2,m,sbk	ss	fm	h	cs
BC	36-85	7.5YR 5/4(B)	7.5YR 5/6fff;RY	2,m,sbk	ss	fm	h	—

KEY- Colour: DRB =Dark Reddish Brown; VPB= Very pale Brown; VPB= Very pale Brown; R= Red; RB= Reddish Brown; LYB= Light Yellowish Brown; Y= Yellow; LB= Light Brown; BI= Black.

Mottles:fff= Few fine faint; cmd= Common medium distinct; fmd= Few Medium Distinct; cff= Common Few Faint; cfd= Common Few Distinct; fmf= Few Medium faint; ffd= Few Faint Distinct.

Structure: 1= Weak; 2= Moderate; 3= Strong; f= Fine, m= Medium; c=coarse; sbk= Sub angular blocky; gr= granular.

Consistence: s= Sticky; ns= Non sticky; ss= Slightly sticky; fr= friable; vfr= Very friable; h= hard; sh= slightly hard; l= loose; s= soft; fm= Firm; Vfm= Very firm; **Boundary:**cw= clear wavy, gw= gradual wavy; dw= diffuse wavy.

Table 2: Summary of Physical Properties of the Soils

Pedon	Horizon	Depth (cm)	Sand %	Silt %	Clay %	TC %	Bulk Density gcm ⁻³	Total Porosity %
BDAES								
OW01	Ap	0-24	67.00	15.00	18.00	SL	1.44	45.66
	AB	24-53	60.00	16.00	24.00	SCL	1.53	42.26
	Btg	53-85	51.00	13.00	36.00	SC	1.79	32.45
	BCg	85-150	38.00	6.00	56.00	C	1.87	29.43

OW02	Ap	0-21	66.00	16.00	18.00	SL	1.73	34.71
	ABg	21-48	50.00	10.00	40.00	SC	1.79	32.45
	Btg	48-95	48.00	10.00	42.00	SC	1.93	27.16
	BCg	93-165	48.00	13.00	39.00	SC	1.95	26.41
OW03	Ap	0-20	65.00	16.00	17.00	SL	1.52	42.64
	AB	20-51	63.00	17.00	22.00	SCL	1.56	41.13
	Bt1	51-96	50.00	11.00	41.00	SC	1.57	40.75
	Bt2g	96-130	36.00	7.00	55.00	SC	1.67	36.98
	BCg	130-160	40.00	7.00	51.00	C	1.87	29.43
BDISG								
OW04	Ap	0-23	81	10	9	LS	1.22	53.96
	AB	23-61	68	13	19	SL	1.52	42.64
	Bt	61-115	68	11	21	SCL	1.52	42.64
	BC	115-180	62	11	27	SCL	1.56	41.13
OW05	Ap	0-20	89	4	7	LS	1.55	42.12
	AB	20-50	80	8	12	SL	1.62	43.02
	Bt1	50-85	80	7	13	SL	1.67	36.92
	Bt2	85-140	70	9	21	SCL	1.73	34.35
	BC	140-200	52	14	35	SCL	1.79	32.45
BDAF								
OW 06	Ap	0-25	84	8	8	LS	1.53	42.26
	AB	25-61	78	8	14	SL	1.58	40.37
	B	61-115	80	8	12	SL	1.66	37.35
	BC	115-170	73	11	16	SL	1.67	36.98
OW 07	Ap	0-25	82	10	8	LS	1.39	48.67
	AB	25-75	84	8	8	LS	1.44	45.66
	Btg	75-120	76	14	10	SL	1.57	40.75
	BCg	120-180	50	22	28	SCL	1.65	37.73
BDFBS								
OW 08	Ap	0-20	68	20	12	SL	1.73	34.71
	AB	20-65	62	17	21	SCL	1.81	31.69
	Bt	65-97	44	8	46	C	1.87	29.43
	Btg	97-135	42	10	50	C	1.97	25.66
	BCg	135-180	38	8	54	C	2.06	22.26
BDLCM								
OW 09	Ap	0-23	87.00	5.00	7.00	LS	1.02	61.50
	AB	23-55	83.00	3.00	13.00	LS	1.10	58.50
	Bt1	55-105	76.00	5.00	19.00	SL	1.14	60.00
	Bt2	105-140	78.00	5.00	17.00	SL	1.15	56.60
	BC	140-180	76.00	4.00	20.00	SCL	1.19	55.10
BDUCM								
OW 10	Ap	0-30	76.00	12.00	12.00	SL	1.52	42.64
	AB	30-75	66.00	16.00	18.00	SL	1.65	37.73
	Bt	75-135	52.00	14.00	34.00	SCL	1.66	37.35
	BC	135-180	52.00	12.00	36.00	SCL	1.73	34.35
BDALM								
OW 11	Ap _g	0-24	62	24	16	SL	1.52	42.64
	AB _g	24-40	60	12	20	SL	1.56	42.26
	BC _g	40-75	58	16	24	SCL	1.72	34.35
OW 12	Ap _g	0-15	50	26	24	SCL	1.45	45.28
	Btg	15-36	46	16	40	SC	1.57	40.75
	BC	36-85	44	16	38	SC	1.67	36.98

Key :TC= Textural class; LS= Loamy Sand; SL= Sandy Loam; SC= Sandy Clay; C= Clay; SCL= Sandy Clay
Chemical Properties

The summary of chemical properties of the soil is presented in table 3. The overall result indicates that the soils were generally acidic (4.20 – 6.50). This confirms earlier study by Afu et al. (2017), that acidic reaction is a characteristic of soils of south eastern Nigeria and that it is the consequence of the acidic nature of the parent rock. The organic carbon content of the soils decreased with soil depth and ranged from (0.46 – 3.04 %) an indication of continuous decomposition of organic materials and sediments which may have slowed decomposition. Also, based on soil fertility ratings of south eastern Nigeria (Enwezor et al., 1990), the area suffered nutrient deficiencies particularly N (0.02 – 0.21 %) and K (0.08 – 1.08 cmolkg⁻¹). Available P of the soils were generally moderate (9.20 – 28.5 mgkg⁻¹). In all the soils, exchangeable cations were low to moderate for calcium (0.10 – 8.80 cmolkg⁻¹), Magnesium (0.60 – 3.80 cmolkg⁻¹) and Sodium (0.006 – 0.38 cmolkg⁻¹). The low availability of the cations could be as a result of low pH (Nwaoba and Lekwa, 2016). Effective Cation Exchange capacity (4.30 – 12.12 cmolkg⁻¹) is low in all the soils except in BDAES (5.28 – 14.68 cmolkg⁻¹) where it was low to moderate. Percentage base saturation was high (63.04 – 91.28 %) in all the soils except in mapping units except for mapping units BDLCM (32.32 – 55.62 %) and BDUCM (25.37 – 38.87 %) where it was low indicating Alfisols and Ultisols respectively. According to Nwaoba et al. (2021), the low overall soil fertility could be associated with repeated history of landscape in the humid and arid climates of Africa in the tertiary geological period. Consequently, most of their basic nutrients might have leached before decomposition.

Table 3: Summary of the chemical properties of the soils

Pedon	Horizon	Depth (cm)	Ph		OC %	OM %	Total N	TEA	EA		Avail P. mkg ⁻³	Exchangeable cation				ECEC	BS %
			H ₂ O	KCL					H ⁺ ...cmolkg ⁻¹	Al ³⁺cmolkg ⁻¹		Ca	Mg	K	Na		
Mapping Unit BDAES																	
OW01	Ap	0-24	6.30	4.50	1.82	3.14	0.27	1.28	1.06	0.22	20.60	8.80	3.80	0.42	0.38	14.68	91.28
	AB	24-53	5.90	4.20	0.68	1.17	0.18	1.22	1.02	0.20	20.00	6.40	3.00	0.37	0.31	11.31	89.21
	Btg	53-85	5.70	4.50	0.64	1.10	0.12	1.38	1.02	0.36	17.40	4.90	2.00	0.21	0.18	8.68	84.10
	BCg	85-150	5.00	4.30	0.57	0.98	0.03	1.48	1.08	0.40	14.10	4.40	1.40	0.09	0.06	7.43	80.08
OW 02	Ap	0-21	4.50	4.00	1.66	2.86	0.13	1.72	1.14	0.58	13.80	4.00	1.80	0.18	0.18	7.88	78.10
	ABg	21-48	4.20	3.80	1.00	1.72	0.08	1.76	1.22	0.54	10.10	4.00	1.60	0.19	0.18	7.73	77.20
	Btg	48-95	4.30	3.90	1.06	1.83	0.07	1.76	1.14	0.62	8.20	2.80	0.60	0.08	0.06	5.31	66.80
	BCg	93-180	4.20	3.70	0.49	0.85	0.04	1.74	1.06	0.68	8.20	2.80	0.60	0.08	0.06	5.28	67.00
OW 03	Ap	0-20	5.50	4.70	0.71	1.22	0.06	1.72	1.06	0.66	10.3	3.40	1.60	0.18	0.12	7.02	75.40
	AB	20-51	5.30	4.50	0.64	1.10	0.06	1.66	1.10	0.56	8.30	4.40	1.00	0.19	0.12	7.46	77.80
	Bt	51-96	5.20	4.40	0.57	0.98	0.05	1.52	1.04	0.48	8.20	3.10	1.40	0.11	0.10	6.24	75.20
	Btg	96-130	5.00	4.30	0.53	0.91	0.05	1.76	1.14	0.62	8.20	2.80	0.60	0.08	0.07	5.31	66.80
	BCg	130-170	4.70	4.00	0.46	0.79	0.05	1.54	0.67	0.48	8.10	4.80	1.40	0.15	0.11	8.00	80.70
Mapping Unit BDISG																	
OW04	Ap	0-23	5.20	4.60	1.38	2.38	0.12	1.68	1.06	0.62	12.90	3.10	1.20	0.18	0.15	6.31	73.37
	AB	23-61	4.90	4.40	0.71	1.22	0.06	1.72	1.06	0.66	10.30	3.40	1.60	0.17	0.13	7.02	75.49
	Bt	61-115	4.90	4.30	0.57	0.98	0.04	1.76	1.08	0.68	9.10	3.00	0.80	0.13	0.09	5.78	69.55
	BC	115-180	4.70	4.10	0.28	0.48	0.02	1.76	1.08	0.68	8.30	2.60	0.80	0.09	0.08	5.33	66.97
OW05	Ap	0-20	5.60	4.90	1.08	1.86	0.05	1.68	1.27	0.41	14.60	3.20	1.40	0.27	0.17	9.66	82.60
	AB	20-50	5.10	4.00	0.93	1.61	0.05	1.71	1.28	0.43	17.30	2.80	1.60	0.19	0.13	8.97	80.93
	Bt1	50-85	4.90	5.10	0.68	1.17	0.05	2.80	2.26	0.54	16.50	3.20	1.40	0.14	0.14	7.68	63.54
	Bt2	85-140	4.50	4.00	0.51	0.25	0.05	1.76	1.31	0.45	13.96	3.40	1.40	0.17	0.17	6.90	74.49
	BC	140-180	4.90	4.00	0.31	0.22	0.06	1.93	1.41	0.52	14.58	3.50	1.41	0.15	0.16	7.15	73.06
Mapping unit BDAF																	
OW 06	Ap	0-25	5.70	5.30	1.07	1.85	0.06	1.58	1.04	0.54	13.30	3.60	1.40	0.13	0.10	6.82	76.83
	AB	25-61	5.80	5.50	0.91	1.57	0.06	1.58	1.04	0.54	14.00	3.80	1.40	0.15	0.11	7.04	77.56
	B	61-115	5.40	4.70	0.64	1.10	0.05	1.66	1.08	0.58	9.80	2.80	0.80	0.09	0.08	5.43	69.42
	BC	115-170	5.50	4.50	0.64	1.10	0.05	1.64	1.04	0.60	9.10	3.00	1.00	0.09	0.07	5.80	71.72
OW 07	Ap	0-25	5.30	4.50	1.38	2.38	0.12	1.68	1.14	0.54	15.40	4.20	1.10	0.21	0.21	7.39	77.36
	AB	25-75	5.10	4.20	1.03	1.78	0.08	1.72	1.18	0.54	15.10	4.00	0.80	0.18	0.14	6.84	74.85
	Btg	75-120	5.50	4.50	1.13	1.94	0.13	1.66	1.10	0.56	13.60	4.40	1.20	0.20	0.17	7.63	78.23
	BCg	120-180	5.50	4.30	0.53	0.91	0.04	1.66	1.10	0.56	10.00	4.40	1.00	0.19	0.12	7.46	77.84
Mapping unit BDFBS																	
OW08	Ap	0-20	6.50	6.00	3.04	5.24	0.21	1.34	5.60	2.40	18.80	5.60	2.40	0.31	0.30	9.95	86.53
	AB	20-65	6.40	5.80	1.81	3.12	0.13	1.38	5.90	2.80	15.20	5.90	2.80	0.34	0.30	10.72	87.13
	Bt	65-97	5.30	4.70	0.53	0.91	0.05	1.54	4.80	1.40	12.10	4.80	1.40	0.16	0.11	8.00	80.75
	Btg1	97-135	5.20	4.40	0.39	0.67	0.03	1.62	3.60	0.80	9.10	3.60	0.80	0.10	0.08	6.20	73.87
	BCg	135-180	4.70	4.00	0.28	0.48	0.02	1.66	3.00	0.80	9.10	3.00	0.80	0.10	0.07	5.63	70.52
Mapping unit BDLCM																	
OW 09	Ap	0-23	5.60	4.80	1.29	2.22	0.13	2.88	2.46	0.42	28.50	1.80	1.60	0.06	0.14	6.48	55.62
	AB	23-55	4.60	4.00	0.59	1.01	0.07	3.04	2.60	0.44	15.50	1.60	1.40	0.04	0.10	6.18	50.81

	Bt1	55-105	4.60	3.90	0.33	0.57	0.06	3.88	3.40	0.48	9.60	1.00	0.70	0.04	0.11	5.73	32.32
	Bt2	105-140	4.50	3.80	0.22	0.38	0.04	3.12	2.64	0.48	9.30	1.30	1.00	0.03	0.10	5.55	43.80
	BC	140-180	4.70	3.60	0.18	0.32	0.03	3.00	2.51	0.49	9.60	1.80	0.80	0.04	0.10	5.14	47.70
	Mapping unit BDUCM																
OW 10	Ap	0-30	5.20	4.30	2.07	3.56	0.16	3.80	3.27	0.53	13.80	1.30	1.12	0.02	0.08	6.32	38.87
	AB	30-75	4.20	4.10	1.53	2.63	0.11	3.20	2.67	0.53	11.10	1.00	0.10	0.02	0.01	4.33	26.09
	Bt	75-135	5.20	4.30	1.41	2.46	0.92	3.60	3.14	0.46	9.80	1.30	0.16	0.05	0.13	5.24	31.28
	BC	135-180	5.30	4.10	0.66	1.14	0.60	2.00	1.46	0.54	9.60	0.10	0.48	0.02	0.08	2.68	25.37
	Mapping unit BDALM																
OW 11	Apg	0-24	5.90	4.80	1.56	2.69	0.06	2.80	2.37	0.43	18.80	5.40	3.40	0.38	0.14	12.12	76.89
	ABg	24-40	5.00	3.80	0.93	1.60	0.01	4.90	4.42	0.48	15.20	3.20	1.30	0.22	0.18	9.84	50.20
	BCg	40-75	5.20	3.60	0.57	0.98	0.05	5.20	4.69	0.51	12.30	3.00	1.80	0.22	0.17	10.39	49.95
OW 12	Apg	0-15	5.80	5.30	1.84	3.17	0.05	1.42	1.38	0.40	16.40	5.20	2.00	0.24	0.22	9.09	84.37
	Btg	15-36	5.20	4.10	0.57	0.98	0.04	1.52	1.04	0.48	11.60	3.10	1.40	0.11	0.10	6.24	75.64
	BC	36-85	4.30	3.90	0.57	0.98	0.04	1.60	1.06	0.54	9.20	2.00	0.60	0.06	0.06	4.33	63.04

Key: O.C= Organic carbon, O.M= Organic matter, N= Nitrogen, TEA= Total Exchangeable Acidity, EA= Exchangeable Acidity, P= Phosphorus, ECEC- Effective Cation Exchange Capacity, BS- Base Saturation

TAXONOMIC CLASSIFICATION OF THE MAPPING UNITS

The taxonomic classification of the soil unit correlated with World Reference Base (WRB) for soil resources is shown in Table 4. Mapping units BDAES (pedons OW 01, OW 02 and OW 03) and BDFBS (pedon 8) were classified as Alfisol because of the presence of argillic horizon and the high base saturation (greater than 35%). They were placed on the suborder-aqualfs because they have in one or more horizons within 50 cm of the mineral soil aquic conditions for some time in normal years (or artificial drainage). They also met the requirement of the great group Endoaqualfs because the soil is saturated with water within 200 cm depth (Soil Survey Staff, 2014). They were further classified as Chromic VerticEndoaqualfs because they have cracks within 125 cm of the mineral soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in normal years and an Ap horizon with a color value and a chroma of 4 or more. The World Reference Base (WRB) correlation is Chromic Luvisols.

Mapping unit BDBAF (pedons OW 06 and 07) and BDISG (pedons OW04 and OW05) were also classified as Alfisols because of presence of argillic horizon and high base saturation ($BS > 35$) and Udalf at the sub order level because they have udic moisture regime. It was further classified as Hapludalf at the great group level and could not be qualified to any specified category at their sub-group levels

which made them to classify as TypicHapludalfs. The prefix Typic defines the central and integrated concept to great group (Sehgal, 2008). The World Reference Base (WRB) correlation is HaplicLuvisols.

Mapping units BDLCM (pedon OW 09) and BDUCM (Soil Unit OW10) was classified as Ultisol because of the argillic or Kandic B horizon with low base saturation ($BS < 35\%$). They have an udic soil moisture regime because within 90 days, the soil moisture control section will not be dry (Soil Survey Staff, 2014). This placed them in Udults at the sub order level. They also met the requirement of the great group Paleudults because they do not have a clay decrease of 20% or more from the maximum clay content and TypicPaleudults because they could not be qualified to any specified category at their sub-group levels. The World Reference Base (WRB) correlation is HaplicAcrisols.

Mapping unit BDALM (Soil units OW 11 and 12) was classified as Alfisol because of the presence of argillic horizon and the high base saturation (greater than 35%). They were placed on the suborder Aqualf because they have in one or more horizons within 50cm of the mineral soil aquic conditions for some time in normal years (or artificial drainage) and Epiaqualfs at the great group level because they have episaturation. The soils were further classified as MollicEpiaqualfs at the sub group level as a result of mollicepipedon. The World Reference Base (WRB) correlation is MollicLuvisols.

Table 4.20: Taxonomic Classification of the Soils

Mapping unit	USDA Soil Taxonomy	World Reference Base (WRB)
BDAES	Chromic VerticEndoaqualfs	Chromic Luvisols (Clayic)
BDISG	TypicHapludalfs	HaplicLuvisols (Clayic)
BDBAF	TypicHapludalfs	HaplicLuvisols (loamic)
BDFBS	Chromic VerticEndoaqualfs	Chromic Luvisols (Clayic)
BDLCM	TypicPaleudults	HaplicAcrisols (Loamic)
BDUCM	TypicPaleudults	HaplicAcrisols (Loamic)
BDALM	MollicEpiaqualfs	MollicLuvisols (Loamic)

CONCLUSION

The soils of the study site were generally acidic. Total nitrogen contents were generally low. The organic matter content of all the mapping units were very low to low, available phosphorus content was generally moderate. Exchangeable Ca^{2+} was very low, Mg^{2+} was low to moderate, Na^+ was very low, K^+ was also low. The soil Order identified in the area were Alfisols and Ultisols according to USDA and correlated to Luvisols and Acrisols of WRB.

RECOMMENDATION

Liming will reduce the acidity and increase effectiveness of fertilizers and growth of arable crops. It will decrease the concentration of toxic elements such as aluminium and create a favourable soil condition for microbial activities. Inorganic and organic manures should be adequately applied to the soils to improve their productive strength. Low land rice needs elements such as N.P.K, Ca, and Mg. Because the soils are generally low in nitrogen, organo-mineral fertilizers or manure should be used to improve the productive capacity of the soils. Soil fertility can be maintained with organic manure either sole or in combination with inorganic fertilizer.

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