LAND CAPABILITY CLASSIFICATION IN RELATION TO ITS CONTRASTING LITHOLOGIES FOR CROP PRODUCTION IN BENDE LOCAL GOVERNMENT AREA SOUTH EASTERN NIGERIA.

[1]Nwaoba, O. W., [2]Iroha J. N., and [1]Okonkwo, E. I.
[1]Department of Soil Science and Land Resources Management,
Michael Okpara University of Agriculture, Umudike, PMB 7267 Umuahia, Abia State, Nigeria
[2]Federal College of land Resources Technology Owerri, Imo State, Nigeria.
Corresponding Author's Email- okezienwaoba@gmail.com
Phone- +2348062311263

ABSTRACT
The soils of Bende Local Government Area (LGA) on diverse lithological formations were characterized and evaluated for their capability for sustainable crop production. A free survey method was used to delineated the soils of the study area into seven (7) mapping units on the basis of soil homogeneity. They include: Bende Asata Nkporo/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 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 (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 results of the land capability classification (LCC) showed that only three classes (II, III and IV) were encountered in the study area and all were in arable crop production class (I - IV). Mapping units BDISG, BDBAF, BDLCM and BDUM fell into land capability class IIn, BDAES and BDFBS mapping units fell into land capability class IIIn while mapping unit BDALM fell into land capability class IVwn. The sub classes 'w', 'n' and 's' were on the grounds of nutrient, wetness and soil texture as limitations. 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: Capability, Lithology, Bende, Southeastern

INTRODUCTION
Soil is a source of raw materials. It acts as a pool to mitigate climate change, protecting anthropological and earthly treasures related to human habitation (Obi, 2018). According to Uboh *et al*. (2020), variability of soils has posed a major constraint for crop production and that variations could arise as a result of parent materials which imply that different soil lithologies give rise to different soil formations.
Parent materials have great influence on soil productivity and its ability to retain nutrients as indicated by its cation exchange capacity (Nwaoba *et al*., 2021). Different parent materials affect the morphology and chemistry of soils under the same conditions, such as topography and vegetation in all geographical regions particularly in the tropics. Jenny, (1980) have stated that changes in physical, chemical and morphological properties of the soil are basically related to parent materials and that a soil landscape pattern often reflects the original parent material.
In Bende LGA, where varying parent materials/ lithologies exist, the overwhelming demand for food and space from a growing population has created several land competitions. Cash crops, fuel, wood, timber production and grazing compete with food crops for the same piece of land (Oti *et al*., 2013; Soil Survey Staff, 2014). However, land users such as farmers, agronomists and extension specialist etc. are more interested in the use for which a piece of land is best suited for, the important crops that can be grown for profit and limitations for one use or several alternative uses and how they can be overcome otherwise known as land evaluation.
Land evaluation is the assessment of land and in some cases changes in the land requirement and qualities. It provides a good link between the basic resource survey and decision making in land use and management. It also helps to provide relevant information about land resources that are necessary for planning, decision making and land resources management for sustainable development (FAO, 2014). Land capability classification groups soils for arable crop production based on their limitations and inherent capabilities and helps to assess suitability of land for cultivation of crops. The knowledge of soil limitations arising from capability classification reports aim at ameliorating such limitations before, or during cropping period (Lin *et al.*, 2005). Therefore, farmers in Bende south eastern Nigeria need knowledge of land capability and nutrient status of the soils to enable them to make good and informed choices on whether to cultivate a land for crop production or use it for livestock production (Lekwa, 2002). Some of the reasons for this situation include

lack of soil survey report of most rural communities where food and fiber production take place. Also, agricultural development in Bende agricultural zone is limited by weak link between agricultural researchers and farmers. This link can be strengthened by translating soil survey reports into simple, self-explanatory maps such as soil fertility maps and land capability maps to aid literate farmers and extension agents to understand and use them unaided (Chukwu and Okonkwo, 2015). Little information is currently available to farmers and extension workers with regard to land management of the varying lithologies/parent materials in agrarian community of Bende Local Government Area of Abia State. In view of this, the research work was carried out to determine soil properties and evaluate the Land capability of the different lithologies in agricultural land of Bende LGA. for sustainable crop production.

MATERIALS AND METHODS

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 5º34ˈ N – 5º56ˈ N and longitudes 7º 38ˈ E – 7º 63ˈ E. Bende LGA, is made up of twelve towns namely; Ezeukwu, Ugwueke, Nkpa, Uzuakoli, Ozuitem, Alayi, Umeimenyi, Mbauzo, Akoli-Imenyi, Igbere, Item and Bende.

Map of Nigeria

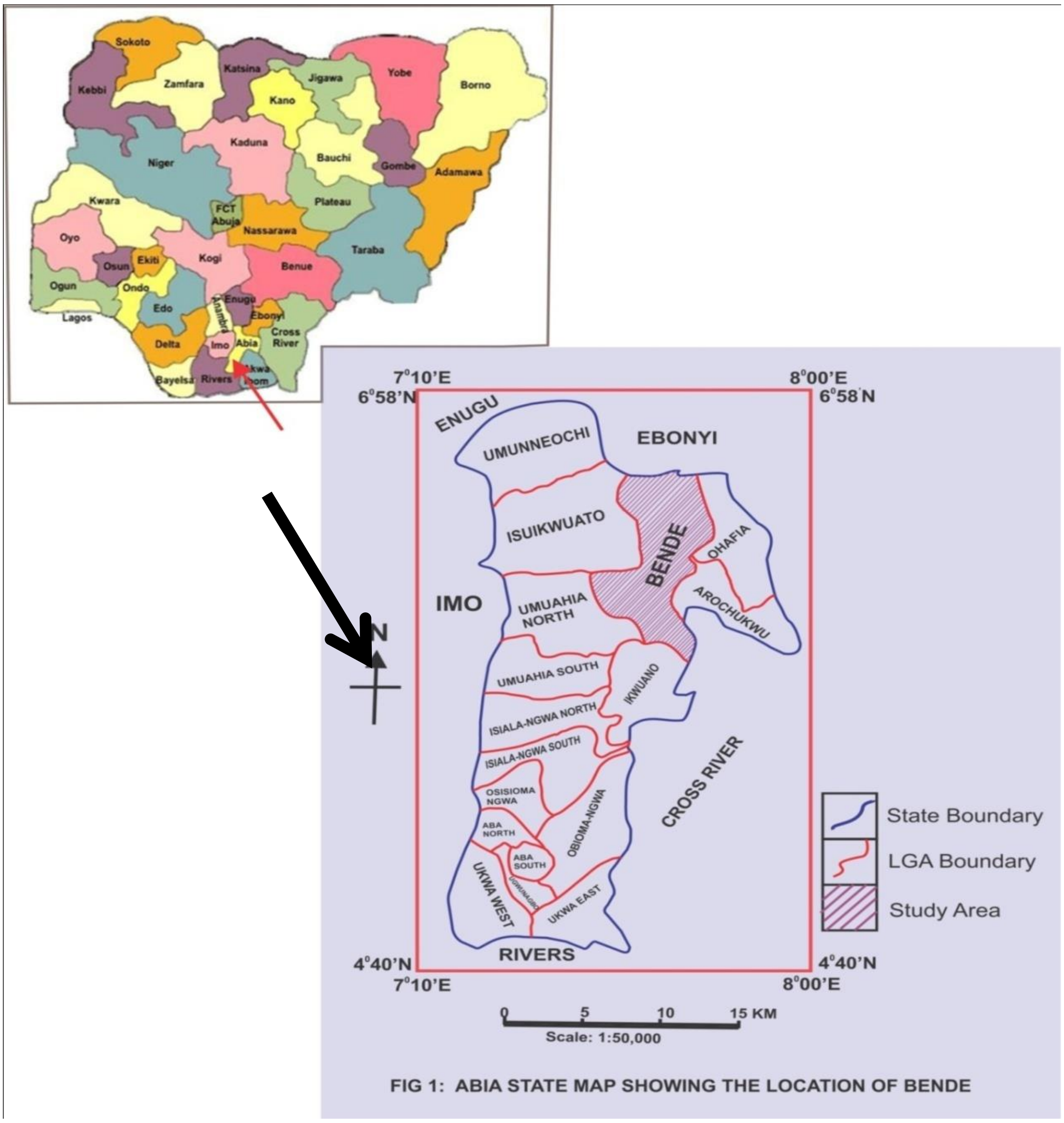

Fig. 1: Map of Nigeria showing the location of Bende Local Government Area
Source: Abia GIS (2020)

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 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.

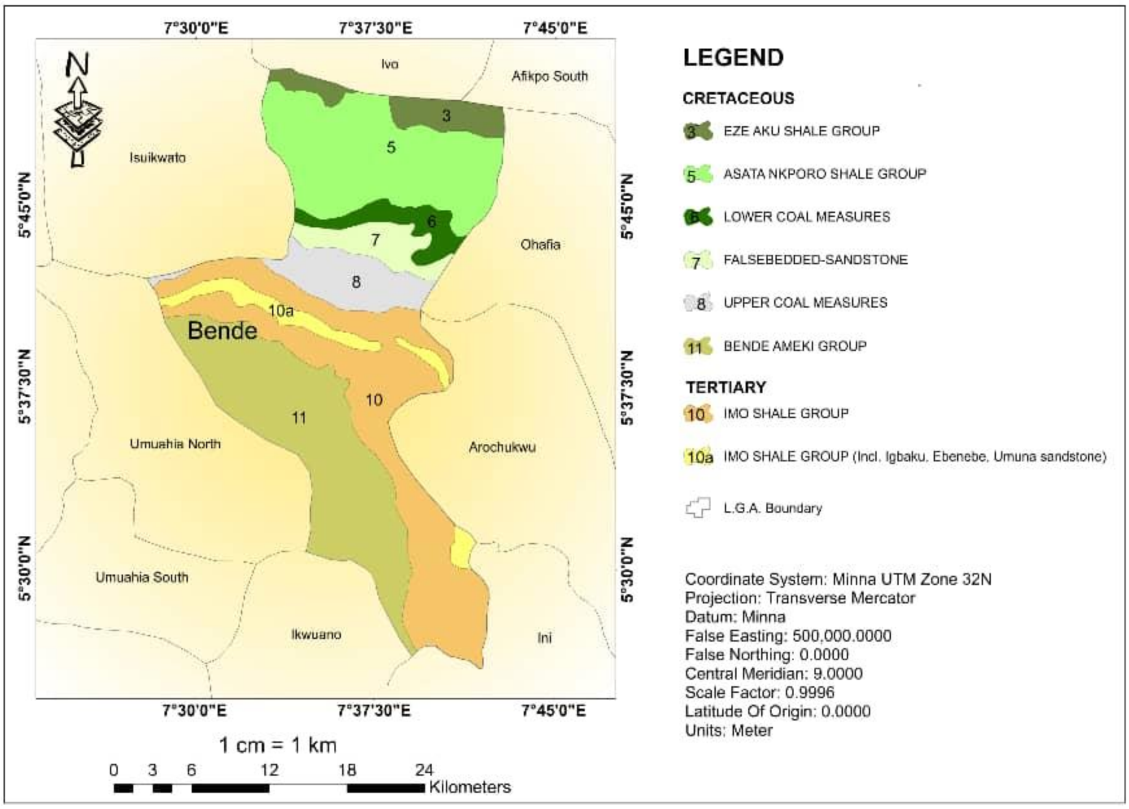

Figure 2: Geologic map of Bende LGA. **Source: Abia GIS (2020)**

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 26ºC and 28ºC. Mean daily maximum temperature is scarcely below 27ºC while the mean daily minimum rarely falls below 18ºC (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 (Oti *et al.,* 2013). The grasses found in the study area are spear grass (*Imperata cylindrica*), guiness grass (*Panicum* maximum), elephant grass (*Pennisetum purperum*). Arable crops include Rice (*Oryza sativa*) and Cassava (*Manihot esculenta*), Yam (*Dioscorea spp*.), Maize (*Zea mays*), Cocoyam (*Colocasia esculentus*). Also, cashew (*Anacardium occidentale*) trees, native pear (*Dacryodes edulis*), mango (*Magnifera indica*), 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 Asata Nkporo/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 Elugwu Akanu for BDAES; Akoli Imenyi and Uzuakoli for BDISG, Nkpa and Okporoenyi for BDBAF, Alayi for BDFBS, Item for BDUCM and Ahaba Imenyi 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.

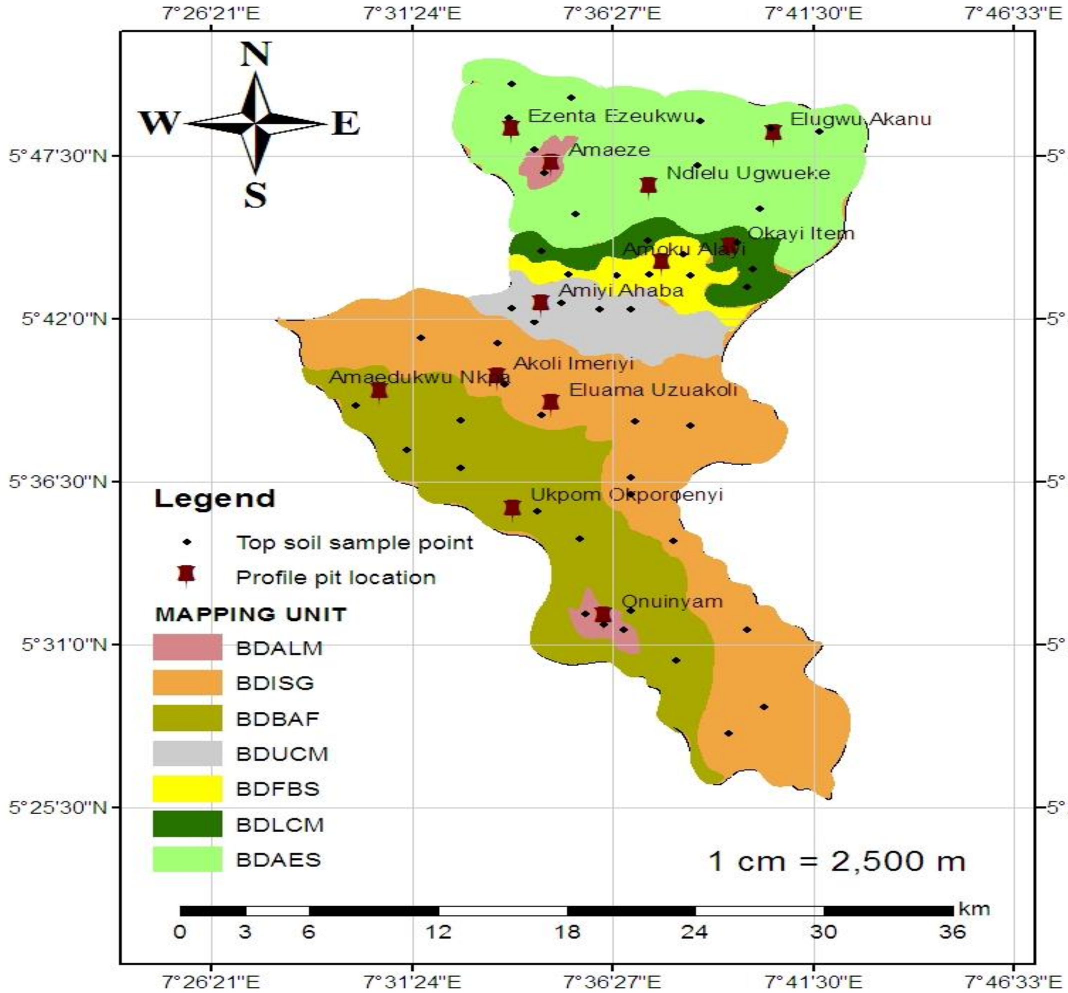

Fig 3: Map of the study area (Bende LGA) showing sampling points

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:

$bd = m \div v$…………… 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:

$Tp = 1 - \{Bd \div Pd\} \times 100$…………. 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 mico-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 $NH4^+$ 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).

ECEC = Exchangeable acidity +Total exchangeable bases (TEB)…………. 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:

$$\%\, BS = \frac{TEB}{ECEC} \times 100 \ldots\ldots\ldots\ldots\ldots. 4$$

Data were interpreted based on Chude *et al*. (2011) and Enwezor *et 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. The potential land use of the study area was evaluated following the USDA land capability classification system (LCC) adapted by Young (1976) and Landon (1991), as described by Akamigbo (2012). Classification was based on soil physical and morphological properties with organic carbon, pH and CEC as the only chemical properties involved. Using the conversion table of the USDA land capability classification, soil limitations in terms of these properties are used to place the soils into different classes with classes I – IV as arable and V – VII as non- arable.

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 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 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 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	Consistence Wet	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(Bl)	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 (Bl)	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; Bl= 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	Apg	0-24	62	24	16	SL	1.52	42.64
	ABg	24-40	60	12	20	SL	1.56	42.26
	BCg	40-75	58	16	24	SCL	1.72	34.35
OW 12	Apg	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 rating s of south eastern Nigeria (Enwezor *et al.,* 1989), 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	Ph		OC	OM	Total N	TEA	EA		Avail P.	Exchangeable cation				ECEC	BS
									H^+	Al^{3+}		Ca	Mg	K	Na		
		(cm)	H_20	KCL	……….. % ………….				…cmolkg^{-1}….		mkg^{-3}	…………………cmolkg^{-1}……………………					%
							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

LAND CAPABILITY CLASSIFICATION

The land capability classification of the different lithologies showing the class and subclasses (limitations) is presented in table 4 (Fig 4) below.

Out of the eight land capability classes in this system, only three (classes II, III and IV) were encountered in the study area and all were in arable crop production class (I - IV). BDISG, BDBAF, BDLCM and BDUCM (pedons OW04,05,06,07,09 and 10) fell into land capability class II and sub class IIn on grounds of nutrient or fertility as limitation, BDAES and BDFBS (pedons OW 01,02,03 and 08) fell into land capability class III and subclass IIIn on grounds of nutrient or fertility as limitation while BDALM (pedons OW11 and 12) fell into land capability class IV and subclass 'w' 'n' and 's' on grounds of wetness, nutrient and soil texture as limitations.

Table 4: Land Capability Classification of the Soil Units

	Mapping units						
Limitations	**BDAES**	**BDISG**	**BDAF**	**BDFBS**	**BDLCM**	**BDUCM**	**BDALM**
Slope (e)%	I	I	I	I	I	I	I
Rock outcrop (r)	I	I	I	I	I	I	I
Wetness (w)	I	I	I	I	I	I	IV
Soil texture (s)	I	I	I	I	I	I	IV
Soil depth (d) cm	I	I	I	I	I	I	I
Fertility (n)	III	II	II	III	II	IV	IV
Land capability class	IIIn	IIn	IIn	IIIn	IIn	IIn	IVwsn

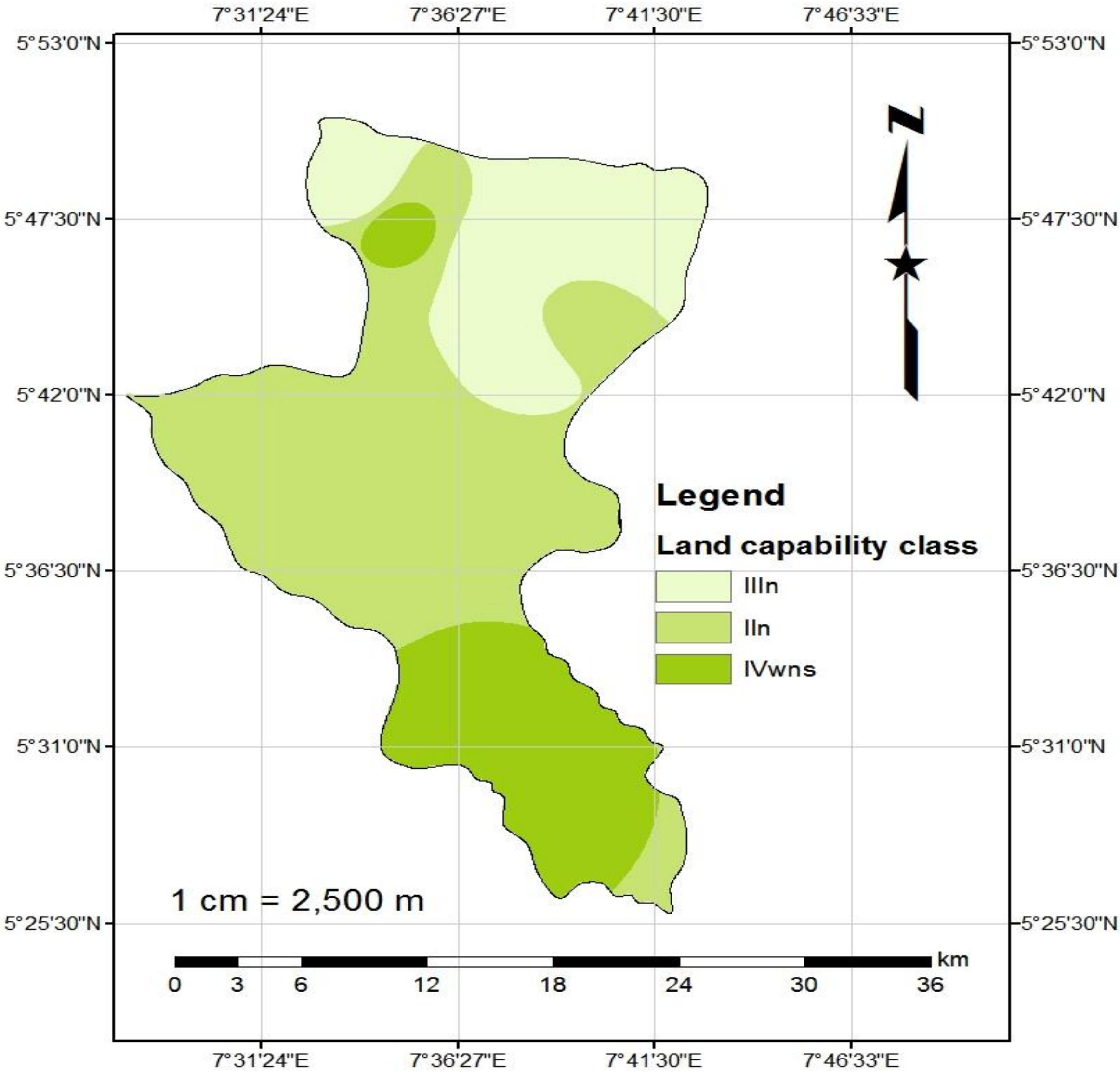

Figure 4: Land Capability Classification map of Bende LGA

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 results of the land capability classification (LCC) showed that only three classes (II, III and IV) were encountered in the study area and all were in arable crop production class (I - IV). Mapping units BDISG, BDBAF, BDLCM and BDUM (pedons OW04,05,06,07,09 and 10) fell into land capability class IIn, BDAES and BDFBS mapping units (pedons OW 01,02,03 and 08) fell into land capability class IIIn while mapping unit BDALM (pedons OW11 and 12) fell into land capability class IVwn. The sub classes 'w', 'n' and 's' were on the grounds of nutrient, wetness and soil texture as limitations.

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.

REFERENCES

Abia State Geographic Information system (GIS) (2020). Abia state geographical Report. Secretariat complex Umuahia, Abia State, Nigeria.

Afu, S. M., Isong, I.A and Aki, E.E., (2017). Variability of selected physico- chemical properties of soils overlying different parent materials in odukpani, Cross River state, Nigeria. *Int. j. of plt. and soil sc.,* 20 (6): 1-14.

Akamigbo, F.O.R and Asadu, C. L. A. (2015). Influence of Parent Materials on the Soils of Southestern Nigeria, *East African Agricultural and Forestry Journal,* 48:1-4, 81-91, DOI: 10.1080/00128325.1982.11663106.

Akamigbo, F.O.R. (2012). Influence of Land Use on Properties of the Humid Tropical Agroecology of South Eastern Nigeria. *Nigeria Agricultural Journal,* Pp 80-89.

Bremner, J. M (1996). Total Nitrogen. In: Sparks, D.L. (Ed.). Methods of Soil Analysis. Part 3. Chemical methods. Book Series 5. *American Society of Agronomy and Soil Science Society of America,* Madison, Wisconsin, pp. 1085-1121.

Chidera, I. (2017). Geology and depositional environment of the Ameki formation in parts of Bende and South Eastern Nigeria. Munich, GRIN Verlag, http: www, grin, com/ document / 434661.

Chukwu, G. O and Okonkwo, E. I. (2015). The roles of a soil pedologist in agro-technology transfer. *Journal of Agriculture and Crops,* 1 (4): 50-56.

Enwezor, W. O., Udo, E. J., Usoroh, N. J., Ayotede, K. A., Adepetu, J. A., Chude, V. O. and Udegbe C. I. (1989). Fertilizer Use and Management Practices for Crops in Nigeria Series, 2: 63-64.

Esu, I.E., (2004). Soil Characterization and Mapping for Food Security and Sustainable Environment in Nigeria. Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria, December 6th -10th, 2004, University of Agriculture, Abeokuta, Nigeria, pp20-24.

FAO (2014). Food and Agriculture Organization of the United Nation. www.fao.org/soils-Portal/Soil-survey/soilproperties/phsyical-peroperties.

Gee, G.W. and Or. D. (2002). Particle Size Analysis. In: Dane, J.H. And G.C. Top (eds) Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. Am. Book Series No.5. ASA and SSSA Maidson. Wl. pg 255-293.

Landon, J.R. (1991). Booker tropical manual. A handbook for soil survey and agricultural Land evaluation in the tropic and subtropics. Longman Inc., New York.

Lekwa, G. (2002). "The Status of Soil Survey in Nigeria. Problems and Prospects". FGN/USDA Soil Survey Workshop Abuja, Nigeria. pp.1-4.

Nigerian Meteorological Agency, NIMET (2017). Evidence of climate change. Climate Review Bulletin 2017, (pp 2-12). Nigerian Meteorological Agency NIMET, Abuja.

Nwaoba, O. W. and Lekwa G. (2016). Characterization and classification of soils of Ndegwu, Owerri west L.G.A, Imo State, Nigeria. *Proceedings of SSN. Calabar, Nigeria. (40) 284-295.*

Nwaoba, O.W., Adesemuyi, E.A and Okonkwo, E.I. (2021). Properties and classification of soils developed under two contrasting parent materials in South East Nigeria. *Int. journal of Agric. and rural Development.* Vol 24(2): Pp. 5894-5904.

Obi, E. A., (2018). Land Capability and Soil Fertility Mapping of Okoko Item for Efficient Fertilizer Use and crop production. Unpublished M.Sc. thesis. Michael Okpara Uni. Of Agric. Umudike, Abia State.

Orajaka, S. O. (1975) Geology. In 'Nigeria in maps. Eastern states'. (Ed. GEK Ofomata) pp. 5-7. (Ethiopes Publishers: Benin City, Nigeria).

Oti, M. R. N., Nwosu, P. O., Oti, E. A. R. N., Chukwu, L. I. and Adiele A. (2013). Evaluation of Indigenous Soil Resource Management Technologies in Bende Local Government Area of Abia State, Nigeria. *International Journal of Applied Research and Technology. 2 (11) 52-58.*

Soil Survey Staff (2014). Key to soil taxonomy: A basic system of soil classification for making and interpreting soil surveys, 12th Ed.

Thomas, G. W. (1996). Exchangeable cations. In: Methods of soil. 2nd Ed., Part 2. Page, A.L., Miller, R.H and Keeney, D.R. (eds). Agronomy Monograph no. 9, Madison, WI. American Society of Agronomy, pp. 159-165.

Ubuoh, E. A, Onwughara, I. J, Ogbonna, P. C. (2020). Soil Physicochemical characteristics along gulley gradients in the selected humid tropical agro- ecological environments in Abia, South Eastern Nigeria. *Journal of erosion and environ. Degradation*. ISSN: 115- 1943.

Young, A. (1976). Tropical Soils. Cambridge University Press. Cambridge 356 p.