TAXONOMIC INFORMATION AND FERTILITY CAPABILITY EVALUATION OF AN AGRICULTURAL LAND IN OLOKORO, UMUAHIA SOUTH, ABIA STATE, NIGERIA.

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ABSTRACT
A field survey, morphological description and laboratory analysis of the soil samples collected were carried out for fertility capability assessment of soils of Olokoro in Umuahia South, Abia State, Nigeria for sustainable production of crops. Five soil mapping units were delineated andone representative pedonestablished in each of mapping units. The pedons were described in-situ for morphological properties. Soil samples collected from the genetic horizons were analysed for physical and chemical properties. The results revealed deep and well drained soils (moist) with friable to firm consistence. The texture of the surface soil was sandy loam overlying sandy clay loam and sandy clay. The soils were very strongly - strongly acid (4.7 to 5.5). Organic carbon (1.5- 1.8%) and available phosphorous contents of the soils (8.6 - 17.9 mgkg^{-1}) were considered moderate. Exchangeable bases were generally low. The cations exchange capacity (CEC) was low with values ranging from 5.8-9.1 cmolkg-^{1}. The soils were Typic Paleudalfs in the USDA Soil Taxonomy and correlated as Haplic Luvisols under WRB classification system.Assessment of the soils' potentials with respect to fertility capability classification (FCC) placed the soils into three FCC units: Lehkm, Lehk and LCehkm covering 8.78, 2.31 and 0.62 % of the study area respectively. The finding identified problems and potentials of the soils and recommends the FCC units spatial maps generated as an advisory tool to farmers and soil scientists to make informed decisions on the appropriate fertility management for sustainable use of the soil.
Keywords: Soil properties, potentials, fertility constraints, sustainable crop production

INTRODUCTION
Heterogeneity of soil and the potentials observed from one location to another have been consequent upon the interplay of soil-forming factors (parent material, climate, organisms, topography and time) to give rise to distinct soil types observed on a landscape (Ojanuga, Okusanmi & Lekwa,2003; Esu, Akpan & Eyong,2008; Amhakhian & Achimugu, 2011).
Taxonomic information on soil properties and distribution is critical for making decisions with regard to sustainable crop production (Lekwa, 2002). In order to avoid a situation whereby prime agricultural land will be lost to other land uses and environmental degradation, there is the need for information on soil characteristics (Akamigbo, 2012; Akpan-Idiok*et. al*., 2013).
Soil is an important non-renewable land resource determining the agricultural potential of a given area (Buol *et al.*, 2003) therefore, its sustainable use is necessary for a successful agriculture to meet the increasing demand of food over a fixed nature of land. The soil resource data provide series of information that may be used to predict of soils' behaviour towards different land uses (crop cultivation, plantation, forest or other usage) (Prasad, 2000). However, utility of the generated data can be significantly enhanced if the taxonomic units are grouped into management units, which can indicate the potential and constraints of an area in terms of its fertility (Akinbola, Anozie & Obi, 2009).
Aderonke and Gbadegesin (2013) reported that poor knowledge and appraisal of parcels of land for agricultural production constitutes the current major problem of agricultural development in Nigeria as it results to poor farm management practices, low yield and an unnecessary high cost of production. The knowledge of soil limitations arising from land evaluation reports aims at ameliorating such limitations before, or during cropping period (Lin *et al.*, 2005).
Pedological information is very important for general land use planning however, the interest of the farmer lies in the interpretation of the soil survey report, otherwise known as land evaluation (Udoh, Ogunkunle & Udeme, 2013; Fasina & Adeyanju, 2006). Fertility capability classification (FCC) identifies the most limiting land qualities and provides a good basis for advising farmers on the appropriate management practice for optimal crop production in an area. Fertility capability classification also simplifies information about the profile and analysis of soils for the benefit of those who are not familiar with soil classification system. It appears to be a suitable framework for agronomic soil taxonomy, which is acceptable to both pedologists and agronomists (Udoh, *et al*., 2013).
Little information is currently available to farmers and extension workers with regard to soil fertility

management in an agrarian community of Olokoro, Umuahia south Local GovernmentArea of Abia State. In view of this, the research work was carried out to determine soil properties and evaluate the fertility capability of agricultural land of Olokoro community for sustainable crop production.

MATERIALS AND METHODS

Study Area

The study was conducted inOlokoro, Umuahia South Local Government Area of Abia state, South-eastern Nigeria. The mean annual rainfall of the area is 2201.92 mm and bimodal with annual temperature ranges from 25 – 27 °C (Nigeria Meteorological Agency, 2020). The soil is underlain by coastal plain sands (Lekwa, 2002; Chukwu, 2013). Land clearing is by slash-and-burn technique while soil fertility regeneration is by bush fallowing whose length has decreased due to anthropogenic activities.

Field method

Following free survey method, the terrain analysis (topographic features such as contour lines) coupled with several auger investigations for morphological attributes (such as colour, texture and consistency) at the depths of 0 - 15, 15 - 30 and 30 – 50 cm were carried out for the establishment of modal profile pits (Fig. 1). 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.

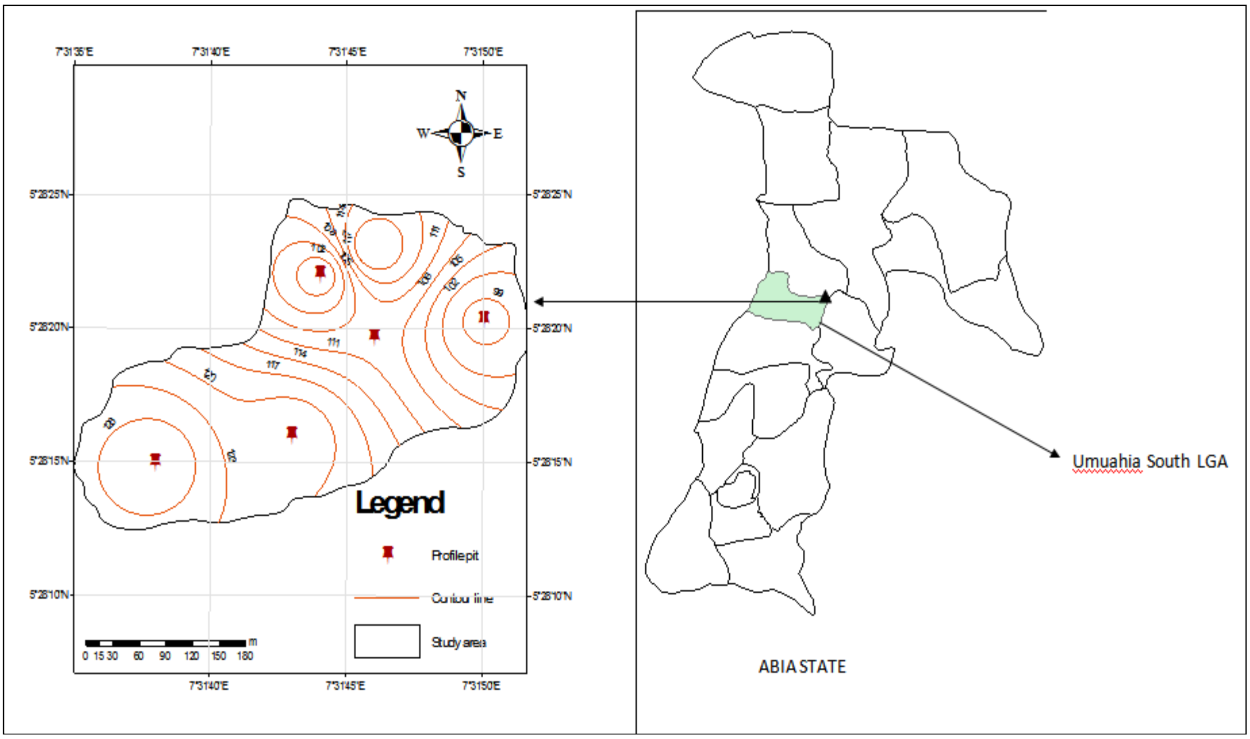

Figure 1: Map of the study area (Olokoro) showing profile pits locations

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, Ibia Ano & Esu (2009: 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:

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

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:

$$Tp = 1 - \{Bd \div Pd\} \times 100 \ldots\ldots\ldots\ldots 2$$

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 Hazelton and Murphy (2015).

Soil classification

Based on the morphological (field data), physical and chemical (laboratory data) properties obtained, the soils were classified using the USDA Soil Taxonomy System (Soil Survey Staff, 2014) and correlated with World Reference Base for soil resources (WRB, 2014).

Evaluation of fertility capability of soils of the study area

The fertility potential of the soils for agronomic management of the chemical and physical properties was evaluated using the fertility capability classification (FCC) system (Sanchez *et al*. 2003). The system consists of three categorical levels: 'type' (texture of plough layer or top 20 cm); substrata type' (texture of sub-soils) and 'modifiers' (soil properties or conditions which act as constraints to crop performance). Class designations from the three categorical levels are combined to form a FCC unit.

Geo-spatial analysis

Arc map-10.3 softwareanalyzed the geo-referenced boundary and elevation data by the (GPS) receiver in GIS to produce the study's area topographic map (Fig. 1). Based on the extent to which the pedons' properties meet the criteria for fertility capability classification - FCC (Tables 3), and concerning the pedon' coordinates; the thematic layer was prepared according to the soil FCC units identified. All the scaled thematic layers were assigned weighted values and integrated into map algebra using interpolation in Arc Map 10.3 software of GIS to produce a fertility capability classification map of the site under study (Fig. 2).

RESULTS AND DISCUSSION

Taxonomic information of soils of the study area

The soils,occurring between nearly flat (1 - 2 % slope gradient) and gently sloping terrain (4 - 5 %) have udic moisture regime. They are very deep (> 175 cm) and well drained with dark brown surface (7.5YR 4/2) colour notation with various shades of brown colour in the subsurface (Table 1). The surface and subsurface horizons of all the pedons were bright and mottle-free. This is indicative of good surface drainage as evidenced by the chroma value colour notation greater than 2. This may be attributed to perhaps, presence of sesquioxides in hydrated form, especially the goethite. (Idoga and Azagaku, 2005).

The surface soil was weak and crumb-structured over moderate and sub-angular structured subsurface. Consistence (moist) varied from friable (surface) to firm in the subsurface and in wet condition, it was non-sticky and non-plastic. Roots concentrated in the upper 30 cm of the soil surface. The friable consistence of the epipedons was an indication of good tillage operation and easy penetration of plant roots. Ojeniyi (2002) reported that a friable soil often has the optimum conditions for tillage operations, resulting in better seedbed preparation with good drainage. The mottle-free condition of the soils may also be attributed to perhaps, presence of sesquioxides in hydrated form, especially the goethite (Udo and Ogukunle, 2012).

Particle-size distribution (Table 2) showed that the surface horizons show high in sand fraction but with a decreasing trend with profile depth (76.40 – 50.40%). Conversely, there was a progressive increase in clay content down the pedal depth (12.60 – 45.60 %). Silt fraction didnot show any definite pattern of distribution down the profile depth. The high sand fraction of the soil indicates that the soils of the study area were characterized by high infiltration rate. This will have good water transmittance but the soil can easily be depleted of essential nutrients and moisture through leaching (Chude, *et al*., 2011). Therefore, good management practices such as the incorporation of organic manure would increase the colloidal properties of the soil for adequate nutrient and water retention and consequently improve the capacity and sustainability of the soil for crop production. The increased clay content observed down the pedal depth could be attributed to a marked pedogenic process of eluviation-illuviation consequent upon high and intense rainfall experienced in the area, leading to clay migration via the network of pores of the coarse texture of the upper horizons (Malagwi, *et al*., 2000). The bulk density values (1.11 – 1.74 gcm^{-3}) were lower than the critical limit values (1.75 – 1.80 gcm^{-3}) for root penetration implying that there is no excessive compaction inhibiting root development.

The chemical properties of the soils (Table 3) showed that pH (H_2O) values ranged from 4.7 to 5.4. This pH range falls within the very strongly to strongly acid class (Chude, *et al*., 2011), The acid nature of the soil could be attributed to high sand fractions resulting to high rate of leaching of bases which is prevalent in the humid tropics. Chude, *et al*. (2011) had established pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for overall satisfactory availability of plant nutrients. This implies that the soils of the study site were not ideal for most crops to thrive well as most nutrient elements especially, phosphorus will be fixed and thus, will not be readily available for absorption by plants in these strongly acid soils (Osodeke and Osondu, 2006). Organic carbon content of the surface horizons ranged from 1.42 to 1.80 %which is considered moderate to relatively high. Consequent upon soil nutrient interpretation of Chude, *et al*., (2011) that soil organic carbon of 1.00-1.50 % and 1.5 – 2.00 % areconsidered moderate and high respectively for crop production, it therefore implies that the soil organic carbon of the area is relatively optimal for crop production. However, the lower surface organic carbon values of pedons 2 and 3 (1.42 – 1.49%) compared to pedon 1 in the area could be consequent upon less vegetal cover attributable to continuous cultivation practiced in the segment of the land area. The subsurface horizons were generally lower in organic carbon than the surface horizons. The reasons for this may be attributed to higher litter falls on the surface horizons and are the points where decomposition of organic materials takes place. Available phosphorous values varied from 10.40 - 17.90 mgkg^{-1} are considered moderate as they are within the range recommended for most commonly cultivated crops (Enwezor., *et al.*, 1989). The observed low level of bases in the soils could suggest leaching as a marked pedogenic process, resulting from the high sand fraction and high acidity in the area (Amusan, *et al*., 2006). The cations exchange capacity (CEC) was low with values ranging from 5.75-9.10 cmolkg-^{1}. Nnaji, *et al*. (2002) observed that, low CEC of a soil could be because of clay type content, high rainfall intensity as well as previous land use.

Table 1: Morphological properties of soils of the study area

Pedon	**Horizon**	**Depth (cm)**	**Colour (Moist)**	**Drainage**	**Slope (%)**	**Structure**	**Consistence**		**Root**	**Boundary**
							Moist	**Wet**		
1	Ap	0.20	5YR	Good	2	2CCr	vfr	ns-	cm	cs
N5.47111	AB	20-38	5YR 3/3,DRB	Good		2CCr	fr	ns-	cf	cs
E7.52861	Bt	38-60	2.5YR	Good		2MSbk	fr	ss-	ff	sw
122 m asl	BtC	60-162	2.5YR	Good		2MSbk	fm	ss-	fvf	-
2	Ap	0 – 20	7.5YR 4/2;Db	Good	3	2CCr	fr	ns-	cm	cg
N5.47083	Bt1	20-45	10YR	Good		2MSbk	fm	ss-	cf	cs
E7.52722	Bt2	45-100	10YR	Good		2MSbk	fm	ss-	ff	cs
128 m asl	BtC	100-	10YR 7/6;Yb	Good		2MSbk	fm	s-p	-	-
3	Ap	0-25	10YR	Good	4	1MCr	fr	ns-	cf	cs
N5.47306	AB	25-65	7.5YR 6/6;Ry	Good		2MCr	fr	ns-	ff	cs
E7.52944	BtcC	65-150	7.5YR 6/8;Ry	Good		2MSbk	fm	ns-	ff	-
N5.47278	Ap	0-20	10YR 5/1;RG	Good	3	2CCr	fr	ns-	cf	cs
E7.52889	Bt	20-62	7.5YR 6/4;LB	Good		2MSbk	fm	ss-	ff	cs
100 m asl	BtC	62-140	7.5YR	Good		2MSbk	fm	ss-	ff	-
N5.47556	Ap	0-30	5YR	Good	2	1MCr	fr	ns-	cm	cs
E7.53056	Bt1	30-60	10YR 5/4;YB	Good		2MCr	fr	ns-	cf	cs
98 m asl	Bt2	60-75	10YR 6/6;BY	Good		2MSbk	fm	ns-np	ff	sw
	BC	75-180	10YR 5/6;	Good		2MSbk	Fm	ss-	fvf	-

Key: Colour: DRB = Dark reddish brown, RB= Reddish brown, Db=Dark brown, DYb=Dark yellowish brown, DGb=Dark grayish brown, Yb=Yellowish brown, Ry=Reddish yellow **Structure**:1=Weak, 2=Moderate, 3=Strong. M=Medium, C=Coarse. Cr=Crumb, Sbk=Sub-angular blocky. **Consistence:** vfr = very friable, fr = friable, fm = firm, vfm = very firm, ns-np = non sticky-non plastic, ss-sp = slightly sticky-slightly plastic, s-p = sticky-plastic. **Root:** ff=fine few, fvf=fine very few, fc=fine common, cf=coarse few, mf=medium few, cm=common medium. **Boundary** cs = clear smooth, g=gradual, cg = clear gradual, sw = smooth wavy.

Table 2: Physical properties of soils of the study area

Pedon	**Depth cm**	**Sand %**	**Silt %**	**Clay %**	**Texture**	**BD gcm^{-3}**	**Porosity %**
1	0.20	70.4	12.0	17.6	SL	1.55	41.5

	20-38	64.4	8.0	27.6	SCL	1.64	38.11
	38-60	58.4	8.0	33.6	SCL	1.65	37.73
	60-162	52.4	7.0	40.6	SC	1.74	34.33
2	0 – 20	76.4	11.0	12.6	SL	1.26	52.45
	20-45	76.4	7.0	16.6	SL	1.37	48.30
	45-100	69.4	10.0	20.6	SCL	1.66	37.35
	100-172	64.4	6.0	29.6	SCL	1.62	38.86
3	0-25	30.4	12.0	17.6	SL	1.61	36.49
	25-65	50.4	10.0	39.6	SC	1.63	38.24
	65-150	46.4	10.0	43.6	SC	1.69	39.22
4	0-20	72.4	10.0	17.6	SL	1.58	40.38
	20-62	54.4	18.0	27.6	SCL	1.88	29.06
	62-140	50.4	4.0	45.6	SC	1.87	29.43
5	0-30	70.4	12.0	17.6	SL	1.11	58.11
	30-60	58.4	8.0	33.6	SCL	1.65	37.73
	60-75	56.4	8.0	36.6	SC	1.76	33.58
	75-180	55.4	8.0	36.6	SC	1.86	29.81

Keys: Texture:SL= Sandy loam, SCL= Sandy clay loam, SC= Sandy clay. BD= Bulk Density

Table 3: Chemical properties of soils of the study area

Pedon	Depth	pH	pH	Avail.P	Total N	OC	OM	Ca	Mg	K	Na	EA		CEC	BS
		H_20	KCl	$mgkg^{-1}$	%	%	%					H^+	Al^{3+}		%
1	0.20	5.08	4.42	16.3	0.186	1.73	2.98	4.8	1.6	0.311	0.294	1.12	0.32	8.13	86.16
	20-38	4.73	4.04	14.5	0.142	1.22	2.10	3.7	0.8	0.288	0.272	1.48	0.48	6.54	77.37
	38-60	4.64	3.72	11.4	0.078	0.71	1.22	4.0	0.8	0.288	0.279	1.66	0.54	7.03	76.34
	60-	4.72	3.84	9.8	0.045	0.37	0.64	3.3	0.6	0.194	0.180	1.78	0.66	6.05	70.64
2	0 – 20	5.06	4.48	15.2	0.134	1.49	2.57	4.6	0.8	0.288	0.251	1.34	0.36	7.28	81.57
	20-45	4.83	4.25	13.9	0.149	1.29	2.22	4.6	1.0	0.302	0.289	1.32	0.34	7.51	82.43
	45-100	5.04	4.22	13.9	0.083	0.95	1.64	4.8	1.2	0.267	0.241	1.28	0.38	7.79	83.54
	100-172	5.03	4.23	12.0	0.052	0.78	1.34	4.7	0.8	0.206	0.122	1.36	0.44	7.19	81.05
3	0-25	5.06	4.48	15.2	0.134	1.49	2.57	4.46	0.8	0.288	0.251	1.34	0.36	7.28	81.57
	25-65	4.84	4.03	8.6	0.050	0.64	1.10	4.6	0.7	0.103	0.089	1.70	0.64	7.19	76.38
	65-150	4.83	4.01	11.4	0.084	0.75	1.30	4.8	1.0	0.262	0.211	1.68	0.68	7.95	78.90
4	0-20	5.25	4.62	15.6	0.144	1.50	2.59	5.0	1.4	0.294	0.266	1.02	0.24	7.98	87.21
	20-62	4.86	4.34	12.2	0.089	0.85	1.47	4.2	0.7	0.242	0.201	1.52	0.48	6.86	77.88
	62-140	4.74	4.11	10.0	0.057	0.78	1.34	4.2	0.6	0.094	0.090	1.64	0.74	6.62	75.29
5.	0-30	5.49	4.96	17.9	0.213	1.80	3.10	5.5	1.8	0.376	0.342	1.08	0.28	9.10	88.10
	30-60	4.93	4.34	14.6	0.109	0.98	1.69	5.0	1.0	0.308	0.296	1.39	0.48	7.99	82.60
	60-75	4.71	4.10	12.1	0.092	0.95	1.63	5.2	1.3	0.311	0.201	1.56	0.56	8.47	81.60
	75-180	4.83	4.33	11.2	0.055	0.85	1.47	5.0	0.6	0.224	0.136	1.68	0.64	7.64	78.01

Classification of soils of the study area

The soils of the area were classified (Soil Survey Staff, 2014) and correlated (World Reference Base, 2014). The evidence of argillic horizons coupled with relatively high base saturation (> 50% by NH_4OAc at pH 7.0) classified the soils of the mapping units at order level as Alfisols. The udic soil moisture regime qualified the units as Udults at suborder level and absence of densic or lithic contact within 150cm of the mineral soil surface and with increasing depth placed them as Paleudalfs at great group level and Typic paleudalfs at sub-group level in the USDA Soil Taxonomy. The strongly acid nature of the soils with low activity argic horizons, weakly developed structure, particularly in the surface and their high base saturation have classified the soils as Haplic Luvisols under WRB classification system.

Fertility capability classification (FCC) of the study area

The fertility classification (FCC) of the study area was done to further interpret the soil taxonomy and give additional soil attributes that are relevant for crop production in a way the farmer can understand. Consequently, the fertility capability classification of the area accessed the fertility potential of the soils for crop production. The fertility capability classification of the soils of the area is shown in Table 5:

Pedon 1, 2, 4 and 5 were associated with loam top soil and subsoil (L) while pedon 3 showed loamy top (L) and clay sub(C) soils. Pedon 2 was grouped into Lehk due to low CEC (e),pH (h) and exchangeable k (k). However, Pedons 1, 4, and 5 were further classified into FCC Units Lehkm and pedon 3 into FCC Units LCehkm due to additional criterion of low organic carbon (m).

Table 3: FCC checklist showing type, substrata type and modifiers

Pedon	Type 1(Topsoil)	Type2(Substrata)	a	e	g	h	i	k	m	s	v	FCC unit
			Condition modifiers									
1	L	L	-	+	-	+	-	+	+	-	-	Lehkm
2	L	L	-	+	-	+	-	+	-	-	-	Lehk
3	L	C	-	+	-	+	-	+	+	-	-	LCehkm
4	L	L	-	+	-	+	-	+	+	-	-	Lehkm
5	L	L	-	+	-	+	-	+	+	-	-	Lehkm
Oil palm	L	C	-	+	+	+	-	+	-	-	-	LCeghk

Key: L = loamy soil; < 35 % clay but not loamy sand or sand, C = clayey soil; > 35 % clay, g = aquic soil moisture regime, v=vertisols (cracking clays), k = low nutrient capital reserves, e = low CEC, a = aluminum toxicity, h = acidic, i = high fixation of P by Fe, s = salinity, m=low organic matter

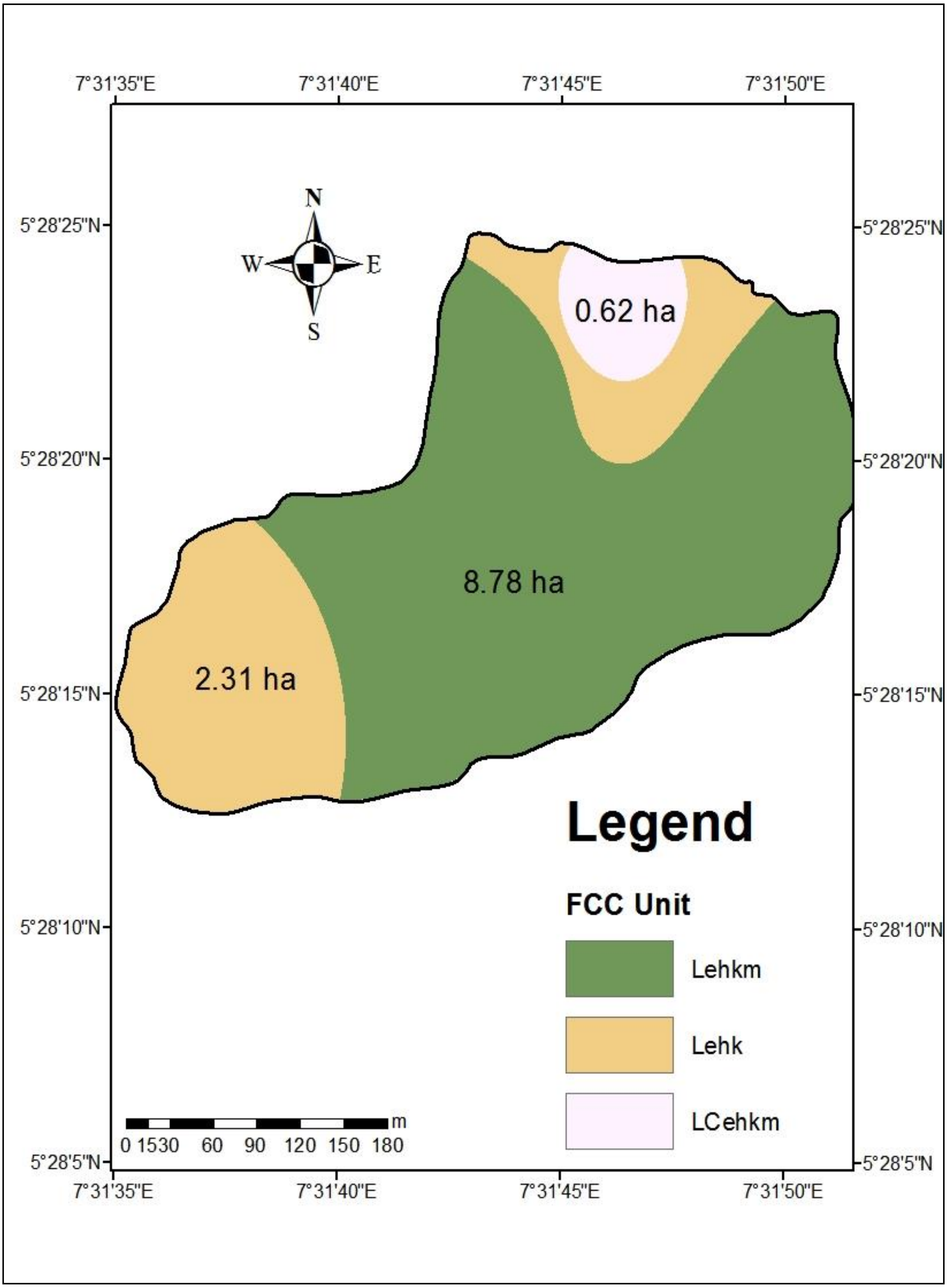

Fig. 2: Fertility capability classification map of the study area

CONCLUSION AND RECOMMENDATION

The study estimated the soil properties of Olokoro, Umuahia South Local Government Area of Abia state, South-eastern Nigeria. and assessed their potentials for sustainable crop production. The finding revealed variability in soil properties and their potentials for sustained crop production. The soils are strongly acid and generally low in low exchangeable bases. The soils' potentials identified three FCC units; Lehkm, Lehk and LCehkm.

The finding therefore, recommends that FCC system is an important tool to evaluate the problems and potentials of varied soils. Thus, the FCC unit spatial map generated is a helpful tool to farmers and soil scientists to make informed decisions on the appropriate fertility management technique to be deployed for sustained use of the soils in the study area.

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