Soil Inventory and Spatial Distribution of Fertility Potential of an Ultisol under Different Land Use Types in Isingwu, Southeast, Nigeria

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ABSTRACT

Soils, under three land use types on an Ultisol in Isingwu, Umuahia North Local Government Area of Abia State, southeast, Nigeria were studied to characterize, classify and asses the fertility potentials thereof. The land use types were arable (AR), five-year fallow (FA) and a fifty year forest (FO). Representative profile soil samples from the land use types were analyzed for their morphological, physical and chemical properties. Geo-spatial technique estimated the spatial distribution of the soil fertility potentials of the soils. Results revealed well drained and deep (> 100 cm) soils; weak to moderate crumb-structure over moderate to strong sub-angular structured subsurface horizons and friable consistence (moist) over firm consistence subsurface horizons. Arable land was less dark in colour (10YR 5/3) compared to other land use types. Silt and clay fractions moderately varied (> 15<35 %) whereas sand fraction did not significantly vary (<15 %). Top soil bulk density of AR, FA and FO were 1.61, 1.41 and 1.29 mg/m^{-3} respectively. Organic carbon was high (1.96 – 2.12%) under FO; moderate (1.52 %) under FA and low (1.37 %) under AR. Cation exchange capacity was generally low (<16.00 cmolkg^{-1}) following this order: AR <FA < FO. The soils of the study site were classified as TypicHapludult (USDA), correlating to HaplicAcrisols (WRB). Assessment of the soils' potentials with respect to fertility capability classification (FCC) placed the soils into two FCC units: Lehkm and Lehk covering 67 % (23.91 ha) and 33 % (11.96 ha) of the study area respectively.

Keywords: Soil properties, classification, fertility distribution.

INTRODUCTION

Deterioration in soil properties sets in the moment land use changes especially, from forest to arable land resulting to loss of soil nutrients (Oguike and Mbagwu, 2009; Asadu*et al.* (2013). Similarly, Ghartey *et al.* (2012) reported that some soil physical and chemical properties are adversely affected by the conversion of a particular land use system to another. Therefore, understanding the characteristics of soils is very important for productive and sustainable management, which in turn is crucial for the sustenance of lives of the inhabitants (Oluwatosin *et al.*, 2006; Fasina and Adeyanju, 2006).

Ultisols are known to be low activity clay soils and are the most cultivated and dominant soils in the south eastern Nigeria (Lekwa, 2002; Ojanuga *et al.,* 2003; Oguike *et al.*, 2006). The organic matter content of some of these soils tends to decline rapidly under continuous cultivation (Oguike and Mbagwu, 2009). Soil nutrients such as nitrogen and phosphorus have been reported to decline with decrease soil organic matter (Chukwu *et al.*, 2007). In this respect, most land use systems in Sub-Saharan Africa can be described as unsustainable, owing to low nutrient resources and negative nutrient budgets (Lal, 2004).

Reports from various research findings have recommended different land management practices, including traditional practices to mitigate the low nutrient levels in tropical soils (Nnaji *et al.*, 2002; Senjobi and Ogunkunle, 2011). The traditional practices such as incorporation of organic matter and crop residues into the soil and crop rotation, agro forestry (using fast growing leguminous trees) have improved organic matter and maintenance of soil quality (Ghartey*et al.* 2012; Ahukaemere *et al.*, 2012) .

The proposal of the Second Development Goal of the United Nations (UN, 2017) to reduce the current and widespread hunger in the developing countries by 2030 can only be achieved if more lands are open for inclusive and sustainable food production. However, inadequacies evident in present-day farm planning procedures require that attention be given to soil survey and land evaluation - the starting point for land-use planning.

Pedological information is very important for general land use planning though, the interest of the farmer lies in the interpretation of the soil surveys otherwise known as land evaluation (Udoh *et al.*, 2013; Fasina and Adeyanju, 2006). Utilizing 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 *et al.*, 2009).

Fertility capability classification (FCC) identifies the most limiting land qualities and provides a good basis for advising farmers on the appropriate management practice for optimum production in an area. FCC 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 Isingwu, Umuahia area of Abia State. In this respect, the research work was carried out to characterize, classify and assess the fertility potentials of soils under selected land use types for sustainable production of crops.

MATERIALS AND METHODS

Study area

The research was carried out inIsingwu community, Umuahia North Local Government Area of Abia state, South-eastern Nigeria (Fig. 1). The climate of Isingwu, Umuahia North in Abia State is marked with two seasons and is characterized by a bimodal heavy precipitation of over 2000 mm yearly withan annual air temperature of 25 -27^0 C and a mean relative humidity of 80 – 90% at the peak of rainy season (Nigeria Meteorological Agency, 2020).

The parent material of the area is coastal plain sand-light textured at the top and with good properties of water infiltration. It is of the Pleistocene Oligocene and consists of unconsolidated yellow and white sand materials which sometimes cross bedded with clays, sandy soils and sandstone (Lekwa, 2002; Chukwu, 2013).

The study area is typical rainforest vegetation in Southeastern agro-ecological zone of Nigeria, and a typology of the degraded humid forest ecology in the Sub-Saharan Africa. The original vegetation of the study area is tropical rainforest which had been reduced to a large extent to a secondary rainforest through human activities. Dominant plant species include cassava (*Manihotspp*), oil palm (*Elaesis guinensis*), maize (*Zea mays* L.), plantain (*Musa spp.*), herbaceous plants and grasses. Land clearing is by slash-and-burn technique while soil fertility regeneration is by bush fallowing. Due to anthropogenic activities, the length of bush fallow has drastically reduced.

Soil sampling and sampling technique

The study area was reconnoitered using footpath to ascertain the feasibility of the study. The boundary of the study site was georeferenced using the global positioning system (Garmin e-trex 10) receiver. Following the free survey method, the entire study site measuring about 35.87 hectares was traversed. Stratified sampling technique was adopted as a result of changes in

vegetation and human influences thus; three land use types were identified; arable (cultivated) land, fallow land and forest land. Five representative profile pits were thereafter established in the identified land use types. The soil profiles pits were examined and described for their morphological attributes (colour, texture, structure, consistence, etc.). The morphological description of the profile was carried out following the standard procedure of FAO (2006). Disturbed (auger) and undisturbed (core) soil samples were collected from identified genetic horizons from the bottom of the profile upward (to avoid cross contamination of the soil samples) and were analyzed in the laboratory for their physical and chemical properties.

Surface (0 – 15 cm) soil samples were collected randomly using soil auger from sample points across the whole study site to obtain the soil fertility status of the site. The perimeter of the site, profile pits and surface soil sample points were georeferenced (Fig. 2).

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): Particle size distribution was determined by Bouyoucos hydrometer 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 and height of the core sampler respectively}.

Total porosity was computed as:

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

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 micro-Kjeldahl method described by Bremner (1996). Available phosphorus was extracted with Bray number I solution of HF and HCl and the P in the extract was determined spectrophotometrically. Cation exchange capacity (CEC) was determined by ammonium acetate (NH_4OAc) of 1.0M leaching at pH 7.The exchangeable bases were extracted by saturating the soil with neutral 1N KCl. The 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).

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

$$\%\,BS = \frac{TEB}{CEC} \times 100 \ldots\ldots\ldots\ldots\ldots\ 3$$

Data were interpreted based on Chude *et al.* (2011) and Hazelton and Murphy (2015) interpretations.

Soil classification

Based on the morphological, physical and chemical 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, 2015).

Assessment of the fertility capability of soils in the study site

The potential of the soils for the kinds of problems they present for agronomic management of the chemical and physical properties was assessed using the fertility capability classification (FCC) system as described by Sanchez *et al.* (1982 and 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.

Statistical analysis

The data generated were analyzed statistically and coefficient of variation (CV) was used to estimate the extent of variability in soil properties within each land use type and calculated as:

$$CV\ (\%) = \frac{\text{Standard Deviation}}{\text{Mean}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 7$$

The CV ranked as low variation (≤ 15 %), moderate variation (≥ 15 ≤ 35 %) and High variation (> 35 %) (Wilding *et al.*, 1994). However, the correlation matrix was used to determine the relationship among the selected properties of the soil. Statistical Analysis System (SAS) computer software (9.4 versions) was used to run the statistical analysis.

Geo-spatial analysis

The spatial data of the site perimeter, profile pits and the surface soil samples were processed in Geographic Information System (GIS) application to produce the map of the project site (Fig. 2). Following the Framework for land evaluation(FAO, 2016), multi-criteria evaluation technique in GIS was used to model fertility indices of the study area. Based on the extent to which the soil properties meet the fertility capability classification (FCC) of the study site and with respect to the coordinates of the sample locations, thematic layers were prepared according to the FCC classes. All the scaled thematic layers were assigned weighted values and integrated into map algebra using Inverse Distance Weighted (IDW) interpolation provided in Arc GIS 10.3 software to produce the nutrient-wise maps of the project site.

RESULTS AND DISCUSSION

Morphological characteristics of the soils under different land use types

The soils (established on slightly sloping terrain (slope gradient of 3-4 %) were generally deep (> 170 cm), well drained and non-concretionary and did not show significant variations in slope, drainage, and water erosion (Table 1). Matrix colour notation (mottle free) ranged from brown (10YR 3/3) surface overlying yellowish brown colours (10YR 5/4) subsurface. However, soils under arable land (cultivated) were less brownish colour (10YR 5/3) compared to other land use types. This could be attributed to low influence of organic matter brought about by less vegetal cover (Brady and Weil, 2012; Uzoho*et al.*, 2007;

Onweremadu*et al.*, 2008). Field soil texture by feel did not significantly vary as all the profiles had sandy loam-dominated surfaces while endopedons were sandy clay loam. All the profiles displayed weak to moderate crumb-structure over moderate to strong sub -angular structured subsurface horizons. Consistence (moist) varied from friable (surface) to firm in the subsurface horizons; and in wet condition it was non-sticky and non-plastic overlying slightly sticky but non -plastic subsurface horizons. Roots concentrated in the upper 30 cm of the soil surface. The friable consistence (moist) observed across the entire land use types as reported by Ogban and Ibia (2006) will enhance good tillage operation and easy penetration of plant roots. The mottle-free condition of the soils may also be attributed to perhaps, presence of sesquioxides (Adesemuyi*et al.*, 2021).

Physical properties of the soils under different land use types

Particle size distribution (Table 2) showed sand fraction ranged from 57.30 – 82.50 %), averaging 71.05 % irrespective of the land use types. The sand fraction though it decreased down the profile depth, it did not show any significant variation down the depth and across the land use types as coefficient of variation (CV) was less than 15 %. The high sand fractions observed across the site may be consequent upon coastal plain sands geology of the area. Previous reports have been acknowledged that parent materials influence soil formation by their different rates of weathering, the nutrient contents for plant use and the dominant particle-size they contain (Akamigbo and Asadu, 1983; Ojanuga, *et al.*, 2003*;* Chukwu, 2013). Contrarily, clay fractions increased progressively and moderately varied down the depth. The mean values of clay fraction were 24.45, 21.28 and 22.94 %; for arable land, fallow land and forest land respectively; indicating non-significant variation in clay content among the land use types studied. 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 mean values (1.57 – 1.65 mgm^{-3}) were lower than the critical limit values (1.75 – 1.80 mgm^{-3}) for root penetration implying that there is no excessive compaction inhibiting root development.

Generally, the Ap horizons of all the soils showed a lower bulk density than the B horizons. The bulk density of the arable land ranged from 1.48 Ap horizon to 1.82 mgm^{-3} in the BtC horizon. Bush fallow had bulk density ranged from 1.41 in the Ap horizon to 1.78 mgm^{-3} in BtC horizon whereas forest land, bulk density varied from 1.29 in the surface to 1.77 mgm^{-3} in the BtC horizon. The higher bulk density observed in arable land contrary to other land use types may be attributed to the mechanical disruption of the pore arrangements by tillage activities and its increase down the pedal depth could be attributed to a decrease in organic matter down the depth. Oguike and Mbagwu (2009) and Sakin*et al.* (2011) reported that changes in land use such as conversion of natural forest to crop land contributed to land degradation that manifested in losses of soil organic matter and reduced stability of the soil aggregates.

The weathering potential of the soils was assessed by silt/clay ratio. This was used to evaluate clay migration, stage of weathering of the soils. The silt/clay ratio ranged from 0.22 – 0.46, indicating that the soils are undergoing high degree of weathering. Yakubu and Ojanuga (2009), and Ayolagha and Opene, (2012) reported that soils with silt/clay ratio less than 0.20 indicate low degree of weathering. The fluctuation in silt/clay ratio with depth could be attributed to the irregular distribution of silt fractions in the profile depths.

Chemical properties of the soils under different land use types

The soil pH (water) ranged from 4.78 in the subsurface to 6.05 in the surface horizons, indicative of very strongly to strongly acid conditions (Table 3). The pH varied minimally (CV <15 %) across the entire land use types. The acid nature of the soil could be adduced to leaching of exchangeable bases encouraged by the high sand fraction (Nkwopara*et al.*, 2019). However, the slight increase in pH values under forest land and fallow land may be consequent upon higher vegetal cover resulting to release of exchangeable bases from decomposed litters and roots (Alemayeha and Sheleme, 2013).

Organic carbon was relatively high (1.96 – 2.12 %) under forest land, moderate (1.52 %) under fallow and low (1.37 – 1.44 %) under arable land. The lower surface organic carbon value observed under arable (cultivated) land compared to other land use types in the area could be consequent upon less vegetal cover attributable to continuous cultivation accompanied by bush burning practiced in the segment of the land area. Similarly, the higher organic carbon observed in the surface horizons compared to the subsurface horizons may be attributed to higher litter falls on the surface horizons and are the points where decomposition of organic materials takes place (Akinrinde and Obigbesan, 2000; Nnaji, *et al.*, 2002).

Continuous tillage operation accounted for the relatively lower organic carbon at the cultivated land; possibly due to increased decomposition and mineralization of organic materials (Onweremadu, *et al.*, 2008).

Variation in total nitrogen was also observed, from low (0.12 -0.14 %) under arable (cultivated) and fallow land to moderate (0.16 – 0.18 %) under forest land use. Available P was moderate (>7.00 $mgkg^{-1}$) under the entire land use types. Exchangeable bases were generally low in all the land use types studied. The low level of bases generally observed in the soils could suggest leaching as a marked pedogenic process, resulting from the high sand fraction in the area.

The decline in fertility of the arable (cultivated) land compared to other land use types might be consequent upon reduction in soil organic carbon and pH due to human activities. Oguike and Mbagwu, (2009) posited that soil properties deteriorate with change in land-use especially from forest to arable land and these changes affect the productivity of the soil.

Classification of Soils of the study site

The soils across the land use types were classified (Soil Survey Staff, 2014) and correlated with WRB (2015). Clay (or soil colloid) movement or accumulation has been clearly demonstrated by the particle size data (Table 2). This signifies the presence of argillic or kandic horizons established in all the land use types because they meet the following requirements: coarser-textured surface horizons over vertically (morphologically) continuous subsurface horizons; CEC within subsurface B horizons that are less than 12 $cmol(+)kg^{-1}$ clay; a regular decrease in organic carbon content with increasing depth; and all these in addition to the requirement of clay content which progressively increased with depth (Table 2) (Soil Survey Staff 2014). The evidence of argillic horizons coupled with low base saturation (< 50% by NH_4OAc at pH 7.0) classifies the pedons into the order Ultisol. The prevalent udic moisture regime (soil solum is not dry in any part for as long as 90 cumulative days in the normal year) of the pedons classified them as Udult. The progressive accumulation of clay in the B-horizons within 150 cm of the mineral soil surface coupled with soil colour (moist) value of 4 or more in the argillic horizons classified the pedons as Hapludult in the Great Group of the USDA Soil Taxonomy (Soil Survey Staff, 2014).

The pedons have no evidence of hydromorphic properties (freely drained) within 150 cm of the mineral soil surface and therefore classified as Typic Hapludult. These were correlated as Haplic Acrisol in the World Reference Base (WRB, 2015).

Agricultural potential of soils of the study site

Soil coding and systematic placement of the soils into fertility capability classification (FCC) units (Table 4) clearly indicates that soil individuals in a single FCC unit do not necessarily belong to the same mapping unit (land use type). All the land use types were associated with loamy top and sub soils (L) as percentage clay values were not more than 35 %. Based on condition modifiers (fertility constraints), arable and fallow land were low in cation exchange capacity (e), pH (h), exchangeable potassium (k) and organic carbon thus, were grouped into FCC unit Lehkm. However, forest land had similar soil characteristics as arable and fallow land but of higher organic carbon therefore classified into FCC unit Lehk (Table 4). The geospatial analysis showed the FCC unit Lehkm covered 23.91 ha while the FCC unit Lehk occupied the remaining 11.96 ha of the study site (Fig. 3).

Conclusion and recommendations

The study inventorized on the selected soils of Isingwu community, Umuahia North Local Government Area of Abia state, Southeast Nigeria and assessed their capability for sustainable crop production. The findings revealed variability in soil properties and their potentials for sustained crop production across the different land use types studied. There were high sand fraction, high acidity, low exchangeable bases and low cation exchange capacity. TypicHapludult (USDA) correlating to HaplicAcrisol (World Reference Base) was the soil type identified. The soils' potentials via fertility capability classification (FCC) identified two FCC units; Lehkm and Lehk.

Therefore, changes in land use type had significant effect on properties of the soils studied. This suggests that conversion of native land to crop land may cause drastic changes in soil properties resulting to land degradation as evidenced in reduction in the soil quality indices.

Following the high acid level of the soils, low fertility and high sand fractions; judicious use of lime and full complements of organic manure and split application of fertilizers are recommended. Crop rotation to mitigate the negative impact of cultivation especially, in the arable (cultivated) land would enhance optimal productivity of the soil.

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Table 1: Morphological characteristics of soil of the study area

Pedon	Horizon	Depth (cm)	Colour (moist)	Drainage	Slope (%)	Structure	Consistence Moist	Wet	Concretion	Pores	Roots	Boundary
			Arable land (cultivated); 5.55966˚N; 7.48498˚E; 110 m above sea level									
1	Ap	0–12	10YR5/3(b)	Well drained	3	w/crumb	friable	ns/np	Absent	c/m	m/cm	cs
	Bt1	12–38	10YR 4/3(b)			m/sbk	firm	ss/np	Absent	f/cm	f/m	cw
	Bt2	38–86	10YR6/4 (lyb)			m/sbk	firm	ss/np	Absent	f/m	f/fw	cs
	BtC	86–174	10YR 5/4 (yb)			s/sbk	firm	ss/np	Few	f/m	-	-
2			**5.55825˚N; 7.48688˚E; 116 m above sea level**									
	Ap	0–15	10YR 4/3(b)	Well drained	4	w/crumb	friable	ns/np	Absent	c/m	m/cm	cs
	Bt1	15–46	10YR6/3 (pb)			w/sbk	firm	ss/np	Absent	f/cm	f/m	gw
	Bt2	46–94	10YR4/4 dyb)			m/sbk	firm	ss/np	V/few	f/m	f/cm	cw
	BtC	94–185	10YR5/8 (yb)			s/sbk	firm	s/sp	Few	f/m	vf/fw	-
			Fallow land (5 years); 5.55672˚N; 7.48667˚E; 111 m above sea level									
3	Ap	0–14	10YR4/3 (b)	Well drained	3	w/crumb	friable	ns/np	Absent	c/m	c/cm	cs
	AB	14–58	10YR 5/3 (b)			w/crumb	friable	ns/np	Absent	c/m	f/m	cw
	Bt	58–107	10YR5/4 (yb)			w/sbk	firm	ss/np	V/few	f/m	f/fw	gw
	BtC	107–189	10YR 5/8 (yb)			m/sbk	firm	ss/np	Few	f/m	-	-
		Forestland (50 years); 5.55753˚N; 7.48503˚E; 111 m above sea level										
4	Ap	0–16	10YR3/3 (db)	Well drained	3	m/crumb	friable	ns/np	Absent	c/m	c/cm	cs
	AB	16-42	10YR 5/3 (b)			m/crumb	friable	ns/np	Absent	c/m	m/cm	cs
	Bt	42-85	10YR 4/6 (dyb)			m/sbk	firm	ss/np	Absent	f/cm	f/cm	cw
	BtC	85–176	10YR 5/6 (yb)			s/sbk	firm	ss/sp	Few	f/cm	f/fw	-
5			**5.5553˚N; 7.48434˚E; 110 m above sea level**									
	Ap	0–20	10YR3/3 (db)	Well drained	3	m/crumb	friable	ns/np	Absent	c/m	c/cm	cs
	AB	20–61	10YR4/3 (b)			m/crumb	friable	ns/np	Absent	c/m	m/cm	gw
	Bt	61–110	10YR 4/6 (dyb)			m/sbk	firm	ss/np	Few	f/cm	f/cm	cw
	BtC	110–192	10YR 5/6 (yb)			s/sbk	firm	ss/sp	Few	f/cm	f/fw	-

Key:Colour: lyb=light yellowish brown, pb=pale brown, b= brown, dyb=dark yellowish brown, db=dark brown, **Structure**: s=strong, w=weak, m=moderate, sbk=sub-angular blocky; **Consistence (wet)**: ns/np-non sticky/non plastic, ss/np=slightly sticky/non plastic, s/sp=sticky/slightly plastic; **Pores/Roots**: c/m=coarse/many, c/cm=coarse/common, f/cm=fine/common, f/m=fine/many, m/cm=moderate/common, f/cm=fine/common, f/m=fine/many, c/m=coarse/many, f/fw=fine/few, vf/fw=very fine/few, f/vfw=fine/very few; **Boundary**:cs=clear and smooth, gw=gradual and wavy, cw=clear and wavy.

Table 2: Physical properties of the soils under different land use types

Pedon	Horizon	Depth (cm)	Sand %	Silt %	Clay %	Texture	BD (mgm^{-3})	Total Porosity	SCR
	Arable land (Mix cropping); 5.55966˚N; 7.48498˚E; 110 m above sea level								
1	Ap	0–12	81.50	3.50	17.00	SL	1.61	0.39	0.22
	Bt1	12–38	72.00	6.00	22.00	SCL	1.59	0.40	0.27
	Bt2	38–86	69.00	5.70	25.30	SCL	1.72	0.35	0.23
	BtC	86–174	60.30	7.10	32.60	SCL	1.78	0.33	0.22
	MEAN		70.70	5.28	24.03		1.68	0.37	0.22
	STDEV		8.74	2.07	6.84		0.09	0.03	0.05
	CV		12.37	39.29	28.48		5.40	9.00	25.33
	5.55825˚N; 7.48688˚E; 116 m above sea level								
2	Ap	0–15	82.40	5.20	12.40	SL	1.48	0.44	0.42
	Bt1	15–46	74.50	4.20	21.30	SCL	1.60	0.44	0.20
	Bt2	46–94	66.70	6.20	27.10	SCL	1.69	0.36	0.23
	BtC	94–185	57.30	5.10	37.60	SC	1.82	0.31	0.14
	MEAN		70.23	5.18	24.60		1.65	0.39	0.25
	STDEV		10.74	0.82	10.57		0.14	0.06	0.12
	CV		14.29	15.81	34.95		8.72	16.51	48.86
	Fallow land (5 years); 5.55672˚N; 7.48667˚E; 111 m above sea level								
3	Ap	0–14	82.50	4.30	13.20	SL	1.41	0.47	0.33
	AB	14–58	78.30	7.70	17.00	SL	1.55	0.42	0.45
	Bt	58–107	71.00	6.70	22.30	SCL	1.62	0.39	0.30
	BtC	107–189	60.30	7.10	32.60	SCL	1.78	0.33	0.22
	MEAN		73.03	6.45	21.28		1.59	0.40	0.33
	STDEV		9.72	1.49	8.42		0.15	0.06	0.10
	CV		13.32	23.12	33.59		9.68	14.54	29.35
4	**Forestland (50 years); 5.55753˚N; 7.48503˚E; 111 m above sea level**								
	Ap	0–16	78.00	5.70	16.30	SL	1.35	0.49	0.35
	AB	16-42	73.40	7.30	19.30	SL	1.50	0.43	0.38
	Bt	42-85	67.40	6.40	26.20	SCL	1.67	0.37	0.24
	BtC	85–176	61.40	5.20	33.20	SCL	1.77	0.33	0.16
	MEAN		70.05	6.15	23.75		1.57	0.41	0.28
	STDEV		7.22	0.91	7.54		0.19	0.07	0.10
	CV		10.30	14.81	31.75		11.80	17.28	35.91
5	**5.5553˚N; 7.48434˚E; 110 m above sea level**								
	Ap	0–20	80.30	6.20	13.50	SL	1.29	0.51	0.46
	AB	20–61	78.30	6.30	18.40	SL	1.51	0.43	0.34
	Bt	61–110	69.20	6.50	24.30	SCL	1.69	0.36	0.27
	BtC	110–192	63.30	4.40	32.30	SCL	1.76	0.34	0.14
	MEAN		72.78	5.85	22.13		1.58	0.41	0.30
	STDEV		7.95	0.97	8.09		0.23	0.08	0.13
	CV		10.93	16.66	31.58		14.38	20.61	44.61

Key: SL = Sandy loam, SCL = Sandy clay loam, LS = Loamy sand, BD=bulk density, SCR=Silt -clay ratio; STDEV = Standard deviation, CV = Coefficient of variation, CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability.

Table 3: Selected chemical properties of soils under different land use types

Horizon	Depth (cm)	pH H_2O	pH KCl	Av. P mg/kg	TN %	OC %	Ca^{+2}	Mg^{+2}	K^{+} cmol/kg	Na^{+}	CEC	EA	Al^{3+}	BS %
	Pedon 1: Arable land (cultivated); 5.55966˚N; 7.48498˚E; 110 m above sea level													
Ap	0–12	5.54	4.68	14.53	0.12	1.37	1.40	1.04	0.24	0.22	9.35	1.63	0.21	31.02
Bt1	12–38	5.39	4.51	15.11	0.08	0.76	2.03	0.72	0.18	0.21	8.07	1.32	0.14	38.91
Bt2	38–86	4.89	4.02	11.16	0.04	0.37	2.20	0.95	0.11	0.15	9.14	1.22	0.16	37.31
BtC	86–174	4.78	3.95	10.22	0.03	0.34	1.61	1.14	0.08	0.12	9.03	1.43	0.23	32.67
MEAN		5.15	4.29	12.76	0.07	0.71	1.81	0.96	0.15	0.18	8.90	1.40	0.19	34.98
STDEV		0.37	0.36	2.43	0.04	0.48	0.37	0.18	0.07	0.05	0.57	0.18	0.04	3.74
CV		7.22	8.39	19.03	60.93	67.58	20.39	18.63	47.10	27.40	6.38	12.55	22.72	10.68
	Pedon 2: Arable land (cultivated): 5.55825˚N; 7.48688˚E; 116 m above sea level													
Ap	0–15	5.35	4.49	17.60	0.14	1.44	2.03	1.18	0.27	0.25	9.87	1.45	0.12	37.79
Bt1	15–46	5.20	4.48	13.45	0.07	0.95	1.64	1.12	0.13	0.19	9.08	1.22	0.09	33.92
Bt2	46–94	4.95	4.10	13.75	0.05	0.55	1.50	1.05	0.06	0.21	9.05	1.24	0.10	31.16
BtC	94–185	4.95	4.26	10.55	0.02	0.40	2.15	0.96	0.06	0.19	9.28	1.35	0.17	36.21
MEAN		5.11	4.33	13.84	0.07	0.84	1.98	1.25	0.13	0.21	9.69	1.32	0.12	36.56
STDEV		0.20	0.19	2.89	0.05	0.47	0.35	0.42	0.10	0.03	1.17	0.11	0.04	4.14
CV		3.86	4.34	20.91	72.84	55.73	17.60	33.81	76.15	13.47	12.08	8.11	29.66	11.33
	Pedon 3: Fallow land (5 years); 5.55672˚N; 7.48667˚E; 111 m above sea level													
Ap	0–14	5.63	4.72	10.14	0.14	1.52	1.44	1.18	0.28	0.21	10.00	1.23	0.31	31.10
AB	14–58	5.41	4.52	9.25	0.10	1.16	1.32	1.03	0.21	0.12	8.07	1.30	0.17	33.21
Bt	58–107	4.89	4.02	11.16	0.04	0.37	1.56	0.95	0.18	0.15	9.02	1.12	0.13	31.49
BtC	107–189	4.78	3.95	10.22	0.03	0.34	1.31	1.11	0.10	0.14	8.61	1.33	0.20	30.89
MEAN		5.18	4.30	10.19	0.08	0.85	1.41	1.06	0.19	0.16	8.94	1.25	0.20	31.59
STDEV		0.41	0.38	0.78	0.05	0.59	0.12	0.09	0.07	0.04	0.83	0.09	0.08	1.12
CV		7.88	8.76	7.66	66.94	69.32	8.35	8.67	38.73	24.99	9.32	7.49	38.12	3.55

Table 3: Selected chemical properties of soils under different land use types (continued)

Horizon	Depth (cm)	pH H_2O	pH KCl	Av. P mg/kg	TN %	OC %	Ca^{2+}	Mg^{2+}	K cmol/kg	Na	CEC	EA	Al^{3+}	BS %
	Pedon 4: Forestland (50 years); 5.55753˚N; 7.48503˚E; 111 m above sea level													
Ap	0–16	6.05	5.17	11.40	0.18	2.12	2.16	1.46	0.37	0.21	10.53	1.25	0.24	39.89
AB	16-42	5.52	4.75	12.45	0.12	1.45	1.65	1.19	0.31	0.17	9.88	1.22	0.10	33.60
Bt	42-85	5.15	4.30	13.72	0.08	1.05	1.70	1.25	0.21	0.18	10.11	1.24	0.11	33.04
BtC	85–176	5.03	4.32	11.18	0.03	0.83	1.35	0.96	0.16	0.15	10.21	1.31	0.15	25.66
MEAN		5.44	4.64	12.19	0.10	1.36	1.72	1.22	0.26	0.18	10.18	1.26	0.15	33.05
STDEV		0.46	0.41	1.16	0.06	0.57	0.33	0.21	0.10	0.02	0.27	0.04	0.06	5.82
CV		8.43	8.90	9.54	61.90	41.58	19.51	16.93	36.19	14.08	2.65	3.09	42.51	17.62
	Pedon 5: Forestland (50 years); 5.5553˚N; 7.48434˚E; 110 m above sea level													
Ap	0–20	5.84	5.01	10.74	0.16	1.96	2.44	1.51	0.35	0.18	11.34	1.28	0.21	39.51
AB	20–61	5.36	4.66	10.06	0.11	1.23	1.82	1.21	0.29	0.14	9.07	1.32	0.19	38.15
Bt	61–110	5.12	4.42	8.92	0.05	0.77	1.56	1.09	0.18	0.15	9.72	1.16	0.16	30.66
BtC	110–192	4.98	4.14	9.11	0.03	0.44	1.31	1.12	0.10	0.13	10.01	1.24	0.21	26.57
MEAN		5.33	4.56	9.71	0.09	1.10	1.73	1.18	0.23	0.15	9.71	1.25	0.19	34.01
STDEV		0.38	0.37	0.85	0.06	0.66	0.40	0.10	0.11	0.02	0.45	0.07	0.02	6.52
CV		7.09	8.10	8.76	67.53	59.87	22.93	8.38	48.55	14.40	4.64	5.47	12.27	19.18

Key: Avail. P=Available phosphorus, OC=Organic carbon, EA=Exchangeable acidity, BS=Base saturation
CV = Coefficient of variation: CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability.

Table4: Fertility capability classification checklist showing type, substrata type and modifiers

Land use type	Type 1 (Topsoil)	Type 2 (Substrata)	a	e	g	h	i	K	m	S	v	FCC unit
			← Condition modifiers →									
Arable land	L	L	-	+	-	+	-	+	+	-	-	Lehkm
Fallow land	L	L	-	+	-	+	-	+	+	-	-	Lehkm
Forest land	L	L	-	+	-	+	-	+	-	-	-	Lehk

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, + = constraint, **-** = no constraint.

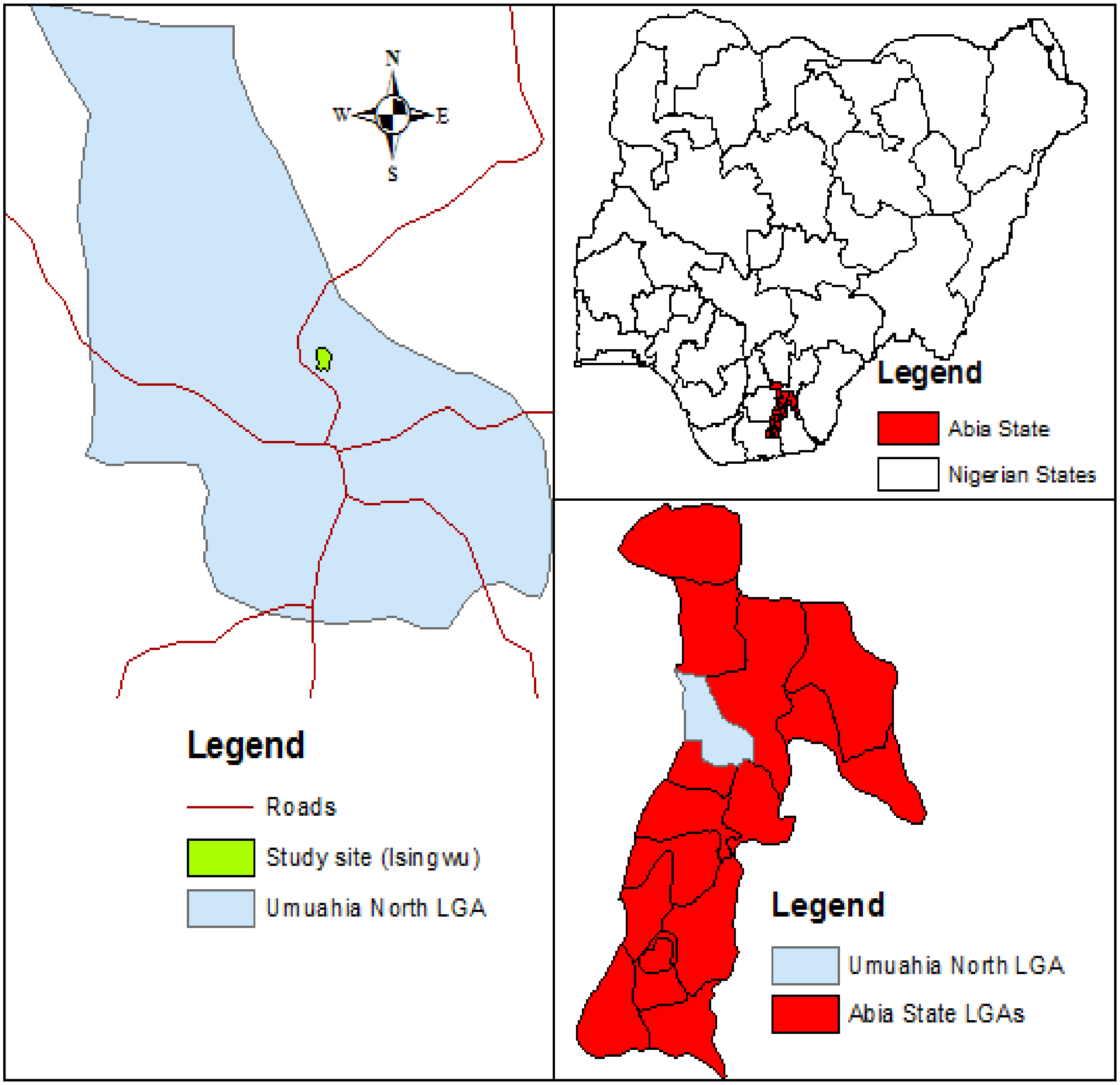
N
W
E
S
Legend
Roads
Study site (Isingwu)
Umuahia North LGA
Legend
Abia State
Nigerian States
Legend
Umuahia North LGA
Abia State LGAs

Fig. 1: Location map of the study area (Umuahia North Local Government Area, Abia State)

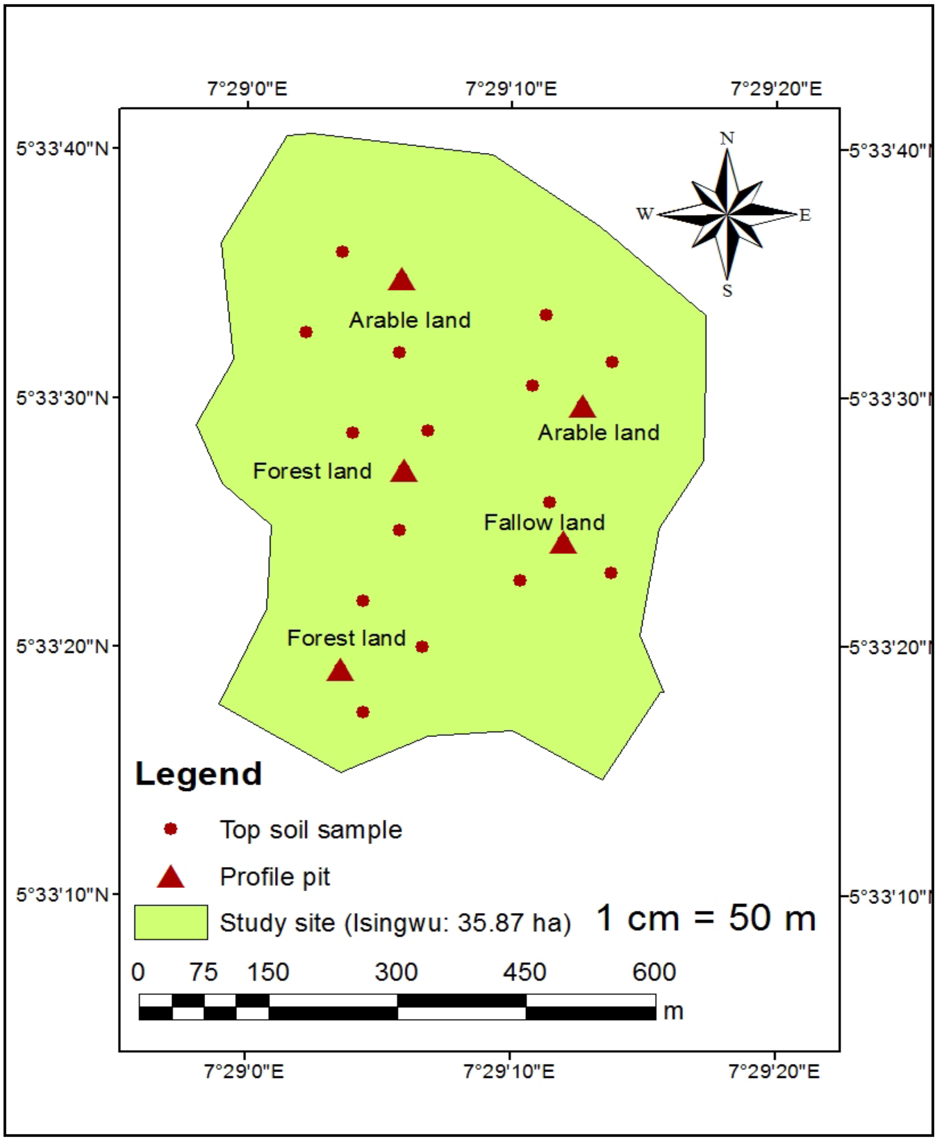

Fig. 2: Map of the study site (Isingwu) showing land use types and sample points.

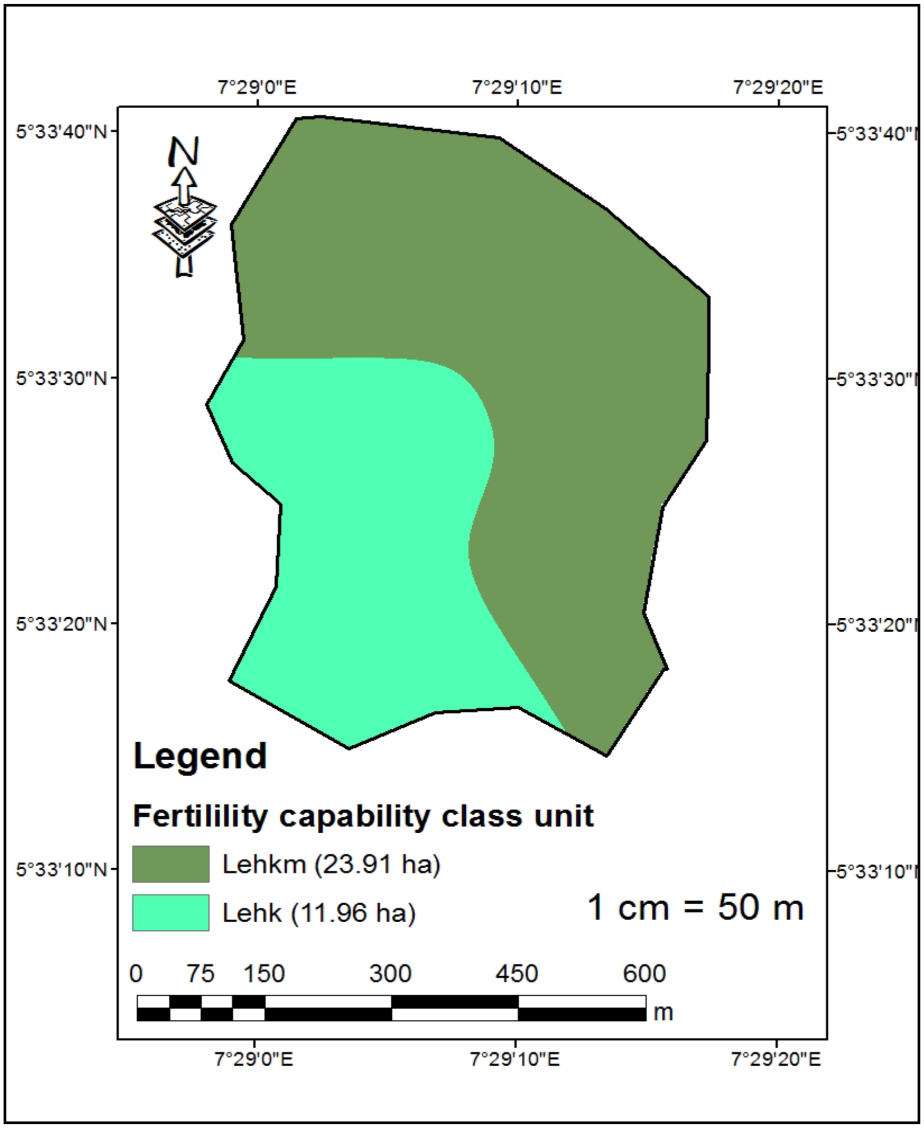

Fig. 3: Spatial distribution of the Fertility capability of the study site