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CHARACTERIZATION AND FERTILITY MAPPING OF AN ACRISOL FOR SITE-SPECIFIC SOIL MANAGEMENT AT OKPORUZOR COMMUNITY, SOUTHEAST NIGERIA

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ABSTRACT

The study characterized and assessed the fertility status of an Acrisol for site-specific soil management at Okporouzor community, Southeastern Nigeria. Following the line transect survey method (east-west), soil samples were investigated. Consequently, changes in physiographic features along the segment formed the basis for delineating the landscape into three mapping units (IJN I–III). Representative profile pits were after that established in the mapping units and described in situ for morphological attributes. Soil samples from profile pits and top soil across the site were analyzed for physical and chemical properties. The geo-spatial technique estimated the spatial distribution of the fertility of the soils. Results revealed well-moderately drained and deep (>100cm) soils. Sandy clay loam overlaid clay in IJN I and sandy loam underlain by sandy clay loam in IJN II and III. Sand fractions varied significantly (CV>35) with depth in IJN I but not (CV<15) in JN II and III. Clay varied (CV>35) with depth across the units. The pH (water) was moderately acidic (4.66-5.91). Organic carbon was high (1.81%) in IJN I and moderate (1.47–1.48%) in IJN II and IJN III, with significant variation (CV>20<42). Available P was moderate (9.81-18.25mgkg-1). Exchangeable bases were generally low except Mg, which was moderate. Cation exchange capacity was low

(<16.00cmolkg-1) following this order: IJN II<IJN III<IJN I. Base saturation was dystric (<50%) across the units. The soils were classified as Haplic Kandiudults (USDA) and Haplic Acrisols (WRB). Soil fertility mapping showed strong acidity (60% area), moderate organic carbon (80%) and low total N (80%). The site was also low in exchangeable Ca (100%) and K (100%) but medium in Mg (100%) and available Phosphorous (100%). The findings of this research are significant, providing a comprehensive understanding of soil fertility and its implications for site-specific soil management.

Keywords: Characterization, Fertility mapping, Management, Site-specific, Soil information

INTRODUCTION

The persistent and widespread hunger and malnutrition across the country may not be reduced to an appreciable level by 2030, as proposed by the Second Development Goal of the United Nations (UN, 2017), which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. This goal underscores the urgency of making more lands available 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 (Esu, 2004). The ability to maximally harness the potential of any soil begins with a detailed survey and correct interpretation of the survey report (evaluation) of that soil (Akinbola *et al*., 2009).

Therefore, soil survey and land evaluation are fundamental to land potential for agricultural purposes and management decisions, planning, and utilization, providing a link between resource assessment and decision-making (Osinuga *et al*., 2020). Soil management and conservation may only be effective if the soil is reliably characterized, classified, and interpreted according to specific crop growth requirements (Akinbola *et al*., 2009). This is very expedient, particularly in this era of constant threats of misuse of soil resources that result in serious degradation, soil erosion and other environmental hazards (Akamigbo, 2010).

Ojanuga *et al*. (2003) reported that the variability of soils over a landscape is consequent upon soil forming factors and, thus, needs an adequate inventory of their characteristics for classification and optimal utilization. The study of soil resources through characterization, classification and evaluation for various land utilization has been reported as one of the strategies to achieve food security and a sustainable environment (Esu, 2004; Ande *et al*., 2008). This aligns with the work of Ogbodo and Chukwu (2012), who state that soil evaluation is a veritable tool used to assess soil health and is a guide to improve soil productivity. Therefore, understanding the fertility status of soils in an area is crucial for the productive and sustainable management of such soils without diminishing the potential for their future use (Ojeniyi, 2002; Chude *et al*., 2011).

Acrisols, which are known to be low-activity clay soils, are the most cultivated and dominant soils in southeastern Nigeria (Lekwa, 2002; Ojanuga *et al.,* 2003; Oguike *et al*., 2006). Low-activity clay soils are characterized by their low cation exchange capacity and poor nutrient retention. 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 decreased soil organic matter (Chukwu *et al*., 2007).

Geographic information system (GIS) is a robust set of tools for collecting, storing, transforming and displaying spatial data from the real world and can be of great use for the assessment and management of soil fertility in precision agriculture (site-specific farming) (Basavaraj *et al*., 2020). This will help the farmers to identify the correct input at the right time and in the right amount, which will not only avoid wastage of inputs but also reduce pollution due to excessive use of inputs. Geospatial techniques, such as GIS, can be used to produce a soil fertility map of an area. This will help formulate balanced fertilizer recommendations and understand the status of soil fertility spatially. Thus, through digital mapping, GIS can be employed in various spheres of agriculture.

In line with the task of feeding the world population, which is estimated to reach 9.5 billion by 2050, there is a need to improve agricultural productivity. A major strategy to achieve this is soil characterization and geospatial fertility mapping. This research has the potential to provide adequate soil information as regards land uses in Okporuzor, an agrarian community that lies in the Umuahia area where important crops like Maize, cassava, yam, potato, plantain, oil palm *etc*., are largely grown. The findings could lead to a significant reduction in environmental degradation and contribute to food security.

In view of this, an attempt was made to characterize and delineate the soil fertility status and prepare the thematic maps of varied soil macronutrients using Geospatial techniques. The findings of this research will ensure site-specific application of soil nutrients and amendments based on spatial variability tailored to the soil requirements. The study will also guarantee appropriate land use by farmers and land use planners using procedures that guarantee a sustainable environment.

MATERIALS AND METHODS

Study Area

The study was conducted in Okporuzor, Afaraukwu, in Umuahia North Local Government Area of Abia State, Southeast Nigeria. The area is located in the rainforest zone of Nigeria. It lies between latitudes 5o29' –5o 42' N and longitudes 7o 29' –7o 33' E (Fig. 1). The area has an average annual rainfall of 2,238 mm distributed over seven months in the rainy season (NRCRI, 2020). Annual air temperatures range between 23o C and 32o, with a relative humidity of 60-80 % (NRCRI, 2020). The study area's vegetation is typical of Nigeria's forest belt. It contains wild oil palm trees of various densities, rubber, and woody shrubs. Land use comprised of arable crops with varying fallow periods that are used as a means of fertility orientation techniques.
The study area is underlain by one main geological formation: the coastal plain sands, which consist largely of unconsolidated sands (Lekwa, 2002). These sands are dominated by low-activity clays with low organic matter content and are susceptible to accelerated erosion and soil degradation (Ogban and Ibia, 2006).

Field Work and Sampling Technique

The study site was reconnoitred for relevant information by observing different physiographic features. Subsequently, a perimeter survey of the land area was carried out, and the project site was geo-referenced using a Global Positioning System (GPS) receiver. Following the line transects survey method, the site was traversed, and five transects at intervals of 100 m apart were cut along the east-west of the study site. Soil samples were investigated consequent upon changes in physiographic features like slope, elevation and drainage along the transects. The observed features formed the basis for delineating the landscape into three mapping units (IJN I – III)

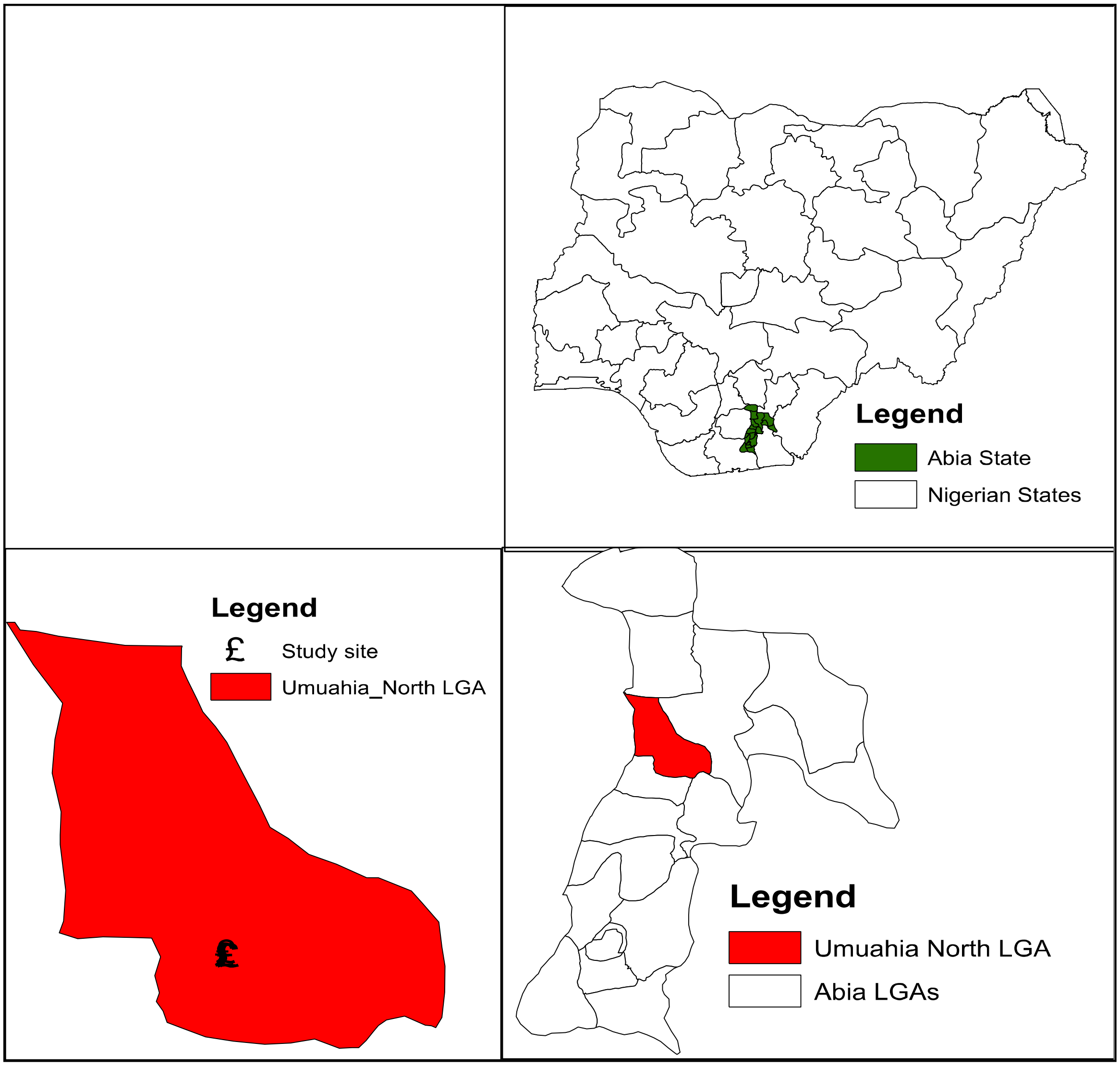

Figure 1: Location map of the study area

Representative profile pits were established in the mapping units delineated. Each profile pit was demarcated into horizons and described *in-situ for* morphological attributes, which was in line with the procedure recommended by FAO (2006). Disturbed and undisturbed (core) soil samples from identified horizons of the profile pits were collected and analyzed for their physical and chemical properties. In addition, top (0 - 20 cm) composite soil samples (each composite sample was taken from six auger samples) were collected in a random pattern across the study site and analyzed for fertility evaluation. All profile pits and top soil sample locations were geo-referenced using a hand-held Global Positioning System (GPS) receiver for geospatial analysis.

Soil Analysis and Data Interpretation

The soil samples were air-dried and ground to pass through a 2 mm sieve. For the determination of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties were carried out following standard laboratory procedures. Particle-size distribution and bulk density were determined by Bouyocous hydrometer methods (Gee and Or, 2002). Undisturbed soil core samples were oven-dried at 105oC to a constant weight, and bulk density was calculated using the formulae

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$$Bulk\ density\ (mg/m^3) = \frac{mass\ of\ oven\ dried\ soil\ sample\ (g)}{Volume\ of\ soil\ sample\ (m^3)}$$ ………… equation 1

Where: v = volume of core sampler {v = π r ^{2} h} {where r is radius (m^2) and h, height (m) of the core sampler}.

Total porosity (Tp) was computed as:

$$Tp = 1 - \{Bd \div Pd\} \times 100$$ ……………………………….. equation 2

Where: Bd = bulk density and Pd = particle density

Soil pH was measured using a 1:2.5 soil-to-water ratio (Thomas, 1996), whereas soil organic carbon was determined by the wet oxidation method of Nelson and Sommers (1982). Total N was determined by the Kjeldahl wet digestion and distillation method (Bremner, 1996). Available P was determined using Bray-2 extract (Olsen and Sommers, 1984). Total exchangeable bases were determined by extracting with neutral normal ammonium acetate (NH4OAc) at pH 7.0. Exchangeable K+ and Na+ in the extract were determined using a flame photometer, while exchangeable Ca2+ and Mg2+ were determined by the ethylene diamine tetraacetic acid (EDTA) titration method (Jackson, 1962). The exchangeable acidity {hydrogen (H+) and aluminium (Al3+)} was determined by titration method. Cation exchange capacity (CEC) was determined by ammonium acetate (NH4OAc) of 1.0M leaching at pH 7 (Jackson, 1962), and finally, the base saturation (BS-%) was determined using the relationship:

$$BS\ (\%) = \frac{\sum Exchageable\ Bases}{\sum Exchageable\ Bases + \sum Exchangeable\ Acidity} \times 100$$ ……… equation 3

Data were interpreted based on Chude *et al*. (2011) ratings for soil data interpretation and fertilizer recommendation from a program organized for crop facilitators from the Agricultural

Development Projects (ADPs) by the Soil Fertility Initiative (SFI) of the National Programme for Food Security (NPFS), Abuja-Nigeria.

Soil Classification

The soils were classified using the USDA soil taxonomy system (Soil Survey Staff, 2014) and World Reference Base (WRB, 2014) soil classification systems based on the morphological, physical, and chemical properties obtained.

Table 1: Nutrient Rating for Soil Data Interpretation

	Very Low	Low	Moderate	High	Very High
Organic Carbon (%)	< 0.4	0.4 – 1.0	1.0 - 1.5	1.5 – 2.0	> 2.0
Total N (%)	< 0.05	0.05 – 0.15	0.15 – 0.25	0.25 – 0.30	> 0.30
Available P (mg/kg)	< 3.0	3.0 – 7.0	7.0 – 20.0	> 20.0	-
Exch. K (cmol/kg)	< 0.2	0.2 – 0.3	0.3 – 0.6	0.6 – 1.2	> 1.2
Exch. Na (cmol/kg)	< 0.1	0.1 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2.0
Exch. Ca (cmol/kg)	< 2.0	2.0 – 5.0	5.0 – 10.0	10.0 – 20.0	> 20.0
Exch.Mg (cmol/kg)	< 0.3	0.3 – 1.0	1.0 – 3.0	3.0 – 8. 0	> 8.0
CEC (cmol/kg)	<6.0	6.0 – 12.0	12.0 – 25.0	25.0 - 40	> 40
Base Saturation (%)	0 – 20	20 - 40	40 - 60	60 - 80	90 - 100
Soil Depth (cm)		**Soil Reaction (H_2O)**			
		(*Acid*)		**(*Alkaline*)**	
Very shallow: < 30		Extremely acidic: < 4.5		Neutral (6.6 – 7.2)	
Shallow: 30-50		Very strongly acidic: 4.5 - 5.0		Slightly alkaline (7.3 - 7.8)	
Moderate: 50 - 100		Strongly acidic: 5.1 - 5.5		Moderately alkaline (7.9 – 8.4)	
Deep: > 100		Moderately acidic: 5.6 - 6.0		Strongly alkaline (8.5 – 9.0)	
		Slightly acidic: 6.1 - 6.5		Very strongly alkaline (> 9.0)	

Source: Chude *et al.* (2011)

Generation of Fertility Maps

Following the Framework for land evaluation, a multi-criteria evaluation technique in GIS was used to model fertility indices of the study area (FAO, 1976). Based on the extent to which the soil properties meet the nutrient rating index (Table 1) and the coordinates of the sample locations, the thematic layer was prepared according to the rating scale as very low, low, medium, and high. 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 soil fertility maps of the area.

RESULTS AND DISCUSSION

Delineation of Mapping Units

The spatial (geo-referenced) data generated from the perimeter, profile pits and the surface soil samples of the farmland were input into the ArcGIS 10.3 software of Geographic Information System (GIS) application to produce the map of the project site (Fig.2). Following the transect survey method; the site was traversed at 100 m interval and soil samples investigated consequent upon changes in physiographic features (slope, elevation and drainage) observed along the traverses. These observable features formed the basis for delineating the landscape into three mapping units (IJN I – III), and representative profile pits were established in the mapping unit delineated (Figure. 2).

The community farmland, covering a total land area of 20.06 ha, was located between altitudes 100 and 115 m above sea level. Mapping unit IJN I covered 2.8 ha (14% area) of the farmland and was situated on an elevation between 111 and 115 m above sea level with gently sloping terrain (3 %). Mapping unit IJN II was also located on gently sloping terrain (4 %) but with lower elevations (105 - 109 m above sea level) and larger area-7.02 ha (35% area) than mapping unit IJN I. Contrarily, mapping unit IJN III occurred on nearly flat slope gradient (2 %) and altitudes between 99 and 103 m above sea level); and covered the largest land area-10. 24 ha (51% area).

Morphological Properties of Soils of the Study Site

The soils across the mapping units were generally deep (> 100 cm), moderately drained and non-concretionary (Table 2). Matrix colour notation ranged from brown (10YR 3/3) surface overlying shades of brownish colour endopedons such as yellowish brown (10YR 5/4), strong brown and brownish yellow (10 YR 6/6). Due to organic matter darkening, A- and B-horizon boundaries were visible. All the profiles displayed weak to moderate crumb structure over moderate, strong sub-angular structured subsurface horizons. The weak and crumb-structured absence of cracks on the surfaces of the units probably inferred that the soils have non-expanding clay minerals, e.g. kaolinite, in them (Alhassan *et al*., 2012). The moist consistency of the surface soil remained friable, whereas the sub-surface soils exhibited firm and slightly sticky/slightly plastic consistency under moist and wet conditions, respectively. However, in mapping unit IJN, I had a sticky and plastic consistency (wet). This may result from higher clay fractions in this unit than other mapping units. The friable surface consistency (moisture) observed across all land use types, as reported by Ogban and Ibia (2006), will enhance tillage operation and the easy penetration of plant roots. The mottle-free condition of mapping units IJN II and III, contrary to mapping unit IJN I, may be attributed to sesquioxides (Adesemuyi *et al*., 2021). By distinctness-topography, all the profiles had clear-smooth, clear-wavy and gradual-wavy horizon borders.

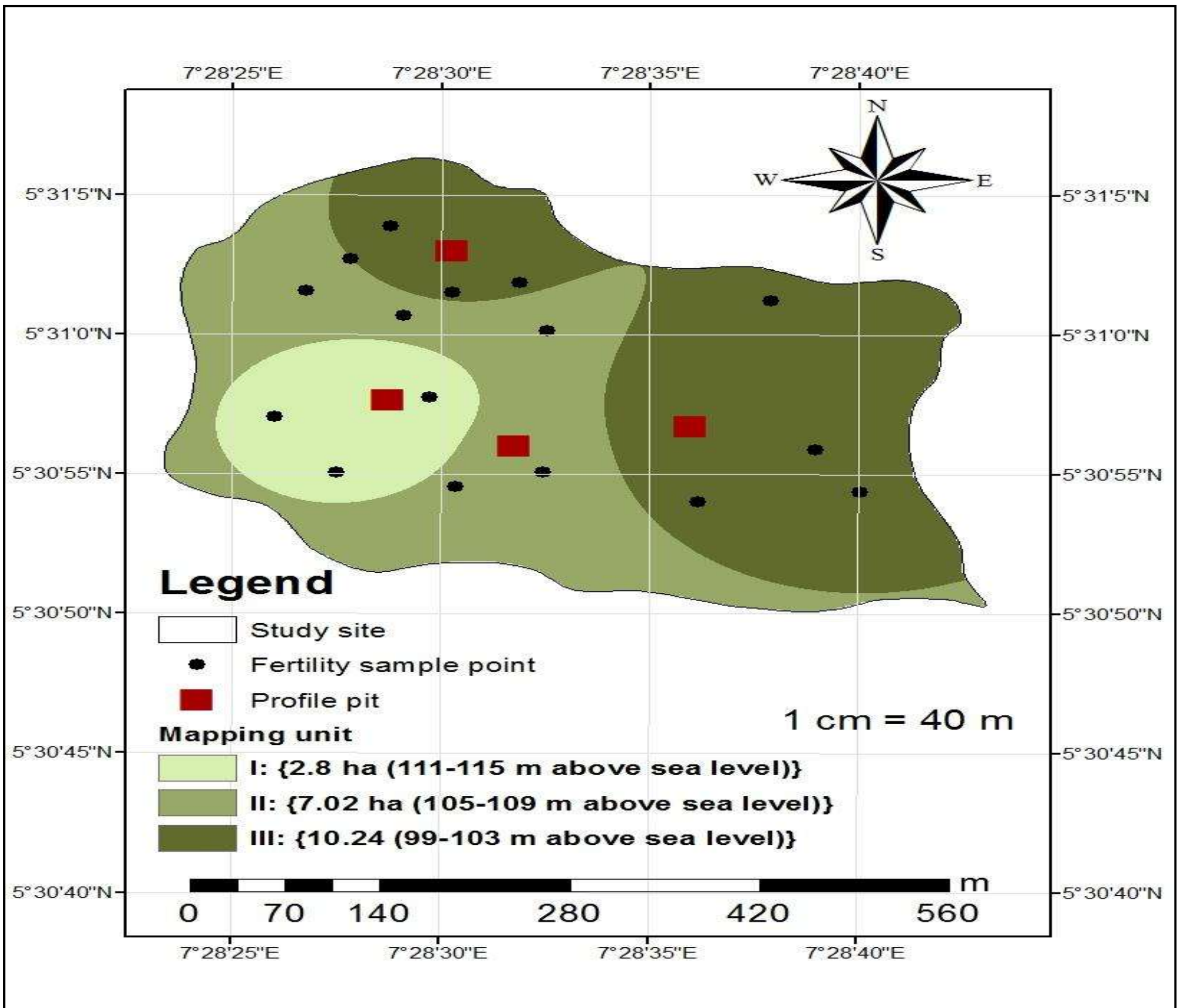

Figure 2: Map of the Study Site Showing Delineated Mapping Units

Physical Properties of Soil of the Study Site

Sand, silt, and clay particle sizes varied from 17 to 77 %, 7.5 to 18 %, and 12 to 66 % across the mapping units. As a result, soil texture ranged from sandy clay loam overlying clay in IJN I, while sandy loam was underlain by sandy clay loam in IJN II and III (Table 3).

Sand fractions varied significantly (CV>35) with depth in mapping unit UIN I, whereas units II and III did not show significant variation (CV<15) with depth. However, clay fractions varied significantly (CV>35) with depth across the mapping units. The clay enrichment in the endopedon is a characteristic of an argillic horizon. This marked eluviation-illuviation process selectively removes clay from the surface layer because sand is less transportable than .finer soil fractions (clay). The average silt/clay ratio was 0.36, 0.48 and 0.55, respectively, for UIN-1, UIN-2 and UIN-3. The silt/clay ratio is above 0.25, indicating that the soils are relatively young, probably indicating that these soils still have weatherable minerals (Lawal *et al*., 2013). The Ap-horizons of mapping units UIN-1, II and III have surface bulk densities of 1.40, 1.29 and 1.48 g·cm - 3respectively (Table 2). These are acceptable values (1.0 - 1.6 mgm-3) for agronomic activities in most mineral soils (Chude *et al.*, 2011; Chaudhari *et al*., 2013). Lower bulk density was generally recorded in the topsoil. This may be adduced to the influence of organic matter on soil bulk density, causing less soil compaction, and its increase down the pedal depth could be attributed to a decrease in organic matter (Oguike and Mbagwu, 2009; Sakin *et al.*, 2011). The total porosity ranged from 40.75 - 51.32 % and decreased with profile depth. Pravin *et al.* (2013) reported that over 50 % of total porosity is ideal for soils; between 45 – 50 % is satisfactory, 40 - 45 unsatisfactory, and 40 % and below are poor.

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Chemical Properties of Soils of the Study Site

The pH (water) ranged from 5.61-5.91 (surface) to 4.66-5.41 (subsurface), indicative of very moderately to strongly acid conditions (Table 4). The pH varied minimally (CV <15 %) across the mapping units. The acidic nature of the sub-surface soils of the site may be attributed to the nature of the parent material (Nnaji *et al*., 2002). Surface organic carbon was relatively high (1.52 – 1.81 %) across the mapping units, with significant variation down the depth. The higher organic carbon observed on the surface compared to the subsurface horizons may be attributed to higher litter falls on the surface horizons, which are the points where the decomposition of organic materials takes place (Akinrinde and Obigbesan, 2000).

Table 2: Morphological properties of soil of the study site

Horizon	Depth (cm)	Colour (moist)	Mottles	Drainage	Slope (%)	Structure	Consistence Moist	Consistence Wet	Concretion	Pores	Roots	Boundary
Mapping unit I (Pedon 2): 5.51601˚N; 7.47466˚E; 115 m above sea level												
Ap	0-10	7.5YR4/2(db)	Absent	Moderate	3	m/crumb	friable	ss/np	Absent	m/fw	c/fw	cs
Bt	10-35	7.5YR 5/4(b)	Absent			m/sbk	firm	s/sp	Absent	f/cm	f/cm	cw
Btc	35-95	7.5YR5/8 (sb)	10YR7/8(ry)			s/sbk	v/firm	s/p	Absent	f/m	f/fw	cs
BtC	95-125	5YR 6/8 (ry)	10R5/4(wr)			s/sbk	v/firm	s/p	Few	f/m	vf/fw	-
Mapping unit II (Pedon 3): 5.51555˚N; 7.4755˚E; 111 m above sea level												
Ap	0–25	10YR 3/3(db)	Absent	Good	4	w/crumb	Friable	ns/np	Absent	m/fw	c/fw	cs
Bt1	25–66	10YR5/3 (b)	Absent			m/crumb	Friable	ns/np	Absent	f/cm	f/cm	cs
Bt2	66–108	10YR4/4 (dyb)	Absent			m/sbk	Firm	ss/sp	Absent	f/m	f/fw	cs
BtC	108–195	10YR5/8 (yb)	Absent			m/sbk	Firm	Ss/sp	Absent	f/m	vf/fw	-
Mapping unit III (Pedon 1): 5.5175˚N; 7.47508˚E; 103 m above sea level												
Ap	0–20	10YR3/3 (db)	Absent	Moderate	2	m/crumb	friable	ns/np	Absent	m/cm	f/cm	cs
Bt1	20–48	10YR 4/4 (dyb)	Absent			w/sbk	firm	ns/np	Absent	f/cm	f/fw	cs
Bt2	48–76	10YR5/3 (b)	Absent			m/sbk	firm	ss/np	Absent	f/m	f/vfw	cs
Bt3	76–129	10YR 5/4 (yb)	Absent			m/sbk	firm	ss/sp	Absent	f/m	-	-
BtC	129-177	10YR 5/6 (yb)	Absent			s/sbk	firm					
Pedon 4: 5.51575˚N; 7.47667˚E; 100 m above sea level												
Ap	0-18	10YR3/3 (db)	Absent	Moderate	2	m/crumb	friable	ns/np	Absent	c/m	m/cm	cs
Bt1	18-45	10YR 5/4 (yb)	Absent			w/sbk	firm	ns/np	Absent	c/m	f/cm	cs
Bt2	45-110	10YR 6/6 (by)	Absent			m/sbk	firm	ss/np	Absent	f/cm	f/fw	cs
BtC	110-173	10YR 5/8 (yb)	Absent			m/sbk	firm	ss/np	Absent	f/fw	f/fw	-

Key: Colour: vdb=very dark brown, b= brown, pb=pale brown, reddish yellow, db=dark brown, rb=reddish brown, sb=strong 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:** /fw=coarse/few, 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

Table 3: Physical Properties of the Soils in the Study Site

Mapping Unit	Pedon	Horizon designation	Depth (cm)	Sand	Silt %	Clay	Textural Class	Bulk Density mg/m^3	Total Porosity %	K-Sat cm^3/hr	Silt/clay
IJN I	**2**	Ap	0-10	53.20	18.40	28.40	Sandy	1.40	47.20	6.81	0.65
		Bt	10 - 35	49.30	12.50	38.20	Sandy	1.53	42.26	2.54	0.33
		Btc	35-95	37.60	10.20	52.20	Clay	1.57	40.75	1.22	0.20
		BtC	95-125	17.30	16.40	66.30	Clay	1.51	43.02	1.23	0.25
MEAN				**39.35**	**14.38**	**46.28**		**1.50**	**43.31**	**2.95**	**0.36**
STDEV				**16.13**	**3.71**	**16.54**		**0.07**	**2.76**	**2.65**	**0.20**
CV				**40.98**	**25.79**	**35.75**		**4.84**	**6.38**	**89.73**	**56.56**
IJN II	**3**	Ap	0–25	77.50	10.20	12.30	Sandy	1.29	51.32	12.60	0.83
		Bt1	25–66	72.30	9.60	18.10	Sandy	1.50	43.40	6.72	0.53
		Bt2	66–108	65.20	7.50	27.30	Sandy	1.74	34.33	2.33	0.27
		BtC	108–195	55.70	10.10	34.20	Sandy	1.76	33.58	2.27	0.30
MEAN				**67.68**	**9.35**	**22.98**		**1.57**	**40.66**	**5.98**	**0.48**
STDEV				**9.44**	**1.26**	**9.70**		**0.22**	**8.39**	**4.88**	**0.26**
CV				**13.95**	**13.49**	**42.23**		**14.14**	**20.64**	**81.61**	**53.71**
IJN III	**1**	Ap	0–20	69.30	12.10	18.60	Sandy	1.39	47.60	9.26	0.65
		Bt1	22–48	61.20	15.30	23.50	Sandy	1.48	44.20	5.34	0.65
		Bt2	48–76	57.60	14.20	28.20	Sandy	1.48	44.20	3.43	0.50
		Bt3	76–129	55.20	10.70	34.10	Sandy	1.50	43.40	2.14	0.31
		BtC	129-177	53.30	8.30	38.40	Sandy	1.75	33.96	2.12	0.22
MEAN				**60.83**	**13.08**	**26.10**		**1.46**	**44.85**	**5.04**	**0.53**
STDEV				**6.31**	**2.79**	**7.94**		**0.14**	**5.13**	**2.99**	**0.20**
CV				**10.38**	**21.31**	**30.44**		**9.26**	**11.44**	**59.27**	**37.16**
	4	Ap	0-18	68.20	14.30	17.50	Sandy	1.57	40.75	13.33	0.82
		Bt1	18-45	60.60	13.40	26.00	Sandy	1.72	35.09	4.52	0.52
		Bt2	45-110	56.00	12.50	31.50	Sandy	1.81	31.69	1.85	0.40
		BtC	110-173	55.20	10.50	34.30	Sandy	1.63	38.49	1.81	0.31
MEAN				**60.00**	**12.68**	**27.33**		**1.68**	**36.51**	**5.38**	**0.51**
STDEV				**5.96**	**1.63**	**7.40**		**0.11**	**3.96**	**5.45**	**0.22**
CV				**9.94**	**12.83**	**27.09**		**6.24**	**10.86**	**101.37**	**43.38**

CV = Coefficient of variation, CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability

Significant variation (CV>35 %) in total nitrogen was also observed, from low (0.13-0.14 %) in mapping units II and III but relatively high (0.18) in unit I. Available P was moderate (>7.00 mg kg-1) and varied moderately with depth across the mapping units. Exchangeable bases (Ca2+ Na+ and K+) were generally low except for exchangeable Mg, which was moderate in all the mapping units. Base saturation provides an indication of how closely nutrient status approaches potential fertility in the soil. Clays have higher base saturation and higher surface area and are more physically and chemically active than sands (Hazelton and Murphy, 2015). Therefore, the generally low base saturation may result from the type and low clay particle size fraction in the area (Table 4).

The general decline in fertility status of the study site might be consequent upon continual cultivation of the soils, resulting in a reduction in soil organic carbon, low exchangeable bases, low base saturation and the acidic nature of the soils. Oguike and Mbagwu (2009) posited that through continuous cultivation, the physical properties and productivity of many soils commonly decline.

Classification of Soils of the Study Site

The soils across the mapping units were classified (Soil Survey Staff, 2014) and correlated (WRB, 2014). The enrichment of clay in the subsurface horizons signifies the presence of argillic or kandic horizons established in all the mapping units 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 4.2) (Soil Survey Staff, 2014). The evidence of argillic horizons coupled with low base saturation (< 50% by NH4OAc at pH 7.0) classifies the pedons into the order Ultisols. The pedons' prevalent udic moisture regime (soil solum is not dry in any part for as long as 90 cumulative days in the normal year) classified them as Udult. The soils had low CEC, indicating low-activity clay and are therefore classified as Kandiudults in the great group with reference to Soil Survey Staff (2014). The progression in 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 all the units as Haplic Kandiudults in the sub-group of the USDA soil Taxonomy (Soil Survey Staff, 2014) and as Haplic Acrisols in the World Reference Base (WRB 2014).

Table 4: Selected Chemical Properties of Soils in the Study Site

Mappin	Pedon	Horizo	Depth (cm)	pH H_2O	pH KCl	Av. P mg/kg	N %	OC %	Ca^{++}	Mg^{++} cmo/kg	K^+	Na^+	EA	CEC	BS %	Al^{3+}
IJN I	**2**	Ap	0-10	5.91	5.17	18.25	0.18	1.81	4.20	2.40	0.23	0.17	1.22	14.62	47.88	0.42
		Bt	10 35	5.24	4.65	15.83	0.10	1.09	3.42	2.10	0.15	0.13	1.36	12.98	44.68	0.46
		Btc	35-95	5.06	4.24	11.66	0.08	1.00	3.12	1.31	0.11	0.09	1.48	11.55	40.03	0.50
		BtC	95-125	5.15	4.36	11.27	0.08	0.89	2.80	1.00	0.11	0.08	1.52	12.23	32.62	0.52
MEAN				**5.34**	**4.61**	**14.25**	**0.11**	**1.20**	**3.39**	**1.70**	**0.15**	**0.12**	**1.40**	**12.85**	**41.30**	**0.48**
STDEV				**0.39**	**0.41**	**3.37**	**0.05**	**0.42**	**0.60**	**0.66**	**0.06**	**0.04**	**0.14**	**1.32**	**6.63**	**0.04**
CV				**7.25**	**8.99**	**23.65**	**43.28**	**34.78**	**17.71**	**38.55**	**37.71**	**35.00**	**9.68**	**10.27**	**16.04**	**9.34**
IJN II	**3**	Ap	0–25	5.64	4.96	16.62	0.13	1.47	3.14	1.81	0.15	0.15	1.42	9.65	54.40	0.48
		Bt1	25–66	5.48	4.76	13.84	0.07	0.79	2.86	1.62	0.13	0.13	1.54	9.88	47.98	0.52
		Bt2	66–108	5.37	4.61	10.23	0.07	0.77	2.05	0.82	0.10	0.08	1.54	8.45	36.09	0.54
		BtC	108–195	4.96	4.21	10.04	0.07	0.63	1.19	0.75	0.10	0.08	1.52	7.94	26.70	0.54
MEAN				**5.36**	**4.64**	**12.68**	**0.09**	**0.92**	**2.31**	**1.25**	**0.12**	**0.11**	**1.51**	**8.98**	**41.29**	**0.52**
STDEV				**0.29**	**0.32**	**3.15**	**0.03**	**0.38**	**0.88**	**0.54**	**0.02**	**0.04**	**0.06**	**0.93**	**12.34**	**0.03**
CV				**5.41**	**6.85**	**24.87**	**35.29**	**41.18**	**38.01**	**43.46**	**20.41**	**32.35**	**3.82**	**10.41**	**29.87**	**5.44**
IJN III	**1**	Ap	0–20	5.61	4.88	17.24	0.13	1.40	3.29	2.21	0.16	0.14	1.28	12.51	46.36	0.44
		Bt1	22–48	5.18	4.52	15.51	0.11	1.17	2.67	2.05	0.15	0.13	1.38	11.77	42.48	0.46
		Bt2	48–76	5.06	4.22	12.81	0.10	1.17	2.61	1.22	0.14	0.12	1.42	11.98	34.14	0.48
		Bt3	76–129	4.87	4.12	12.24	0.08	0.92	1.50	0.81	0.11	0.09	1.58	9.33	26.90	0.54
		BtC	129-177	4.81	4.10	12.32	0.08	0.84	1.48	0.65	0.10	0.09	1.56	9.81	23.65	0.42
MEAN				**5.11**	**4.37**	**14.02**	**0.10**	**1.10**	**2.31**	**1.39**	**0.13**	**0.11**	**1.44**	**11.08**	**34.71**	**0.47**
STDEV				**0.32**	**0.33**	**2.24**	**0.02**	**0.22**	**0.79**	**0.71**	**0.03**	**0.02**	**0.13**	**1.41**	**9.74**	**0.05**
CV				**6.23**	**7.60**	**15.99**	**21.21**	**20.32**	**34.39**	**51.21**	**19.61**	**20.19**	**8.73**	**12.77**	**28.07**	**9.84**
	4	Ap	0-18	5.58	4.82	15.08	0.15	1.55	3.08	2.03	0.18	0.15	1.36	11.17	48.70	0.46
		Bt1	18-45	5.30	4.60	14.11	0.10	1.02	2.67	1.42	0.14	0.13	1.46	10.26	42.50	0.48
		Bt2	45-110	5.06	4.25	10.43	0.07	0.81	2.11	1.09	0.11	0.10	1.54	10.67	31.96	0.52
		BtC	110-173	4.66	4.02	9.81	0.06	0.80	2.05	1.01	0.12	0.10	1.56	9.34	35.12	0.52
MEAN				**5.15**	**4.42**	**12.36**	**0.10**	**1.05**	**2.48**	**1.39**	**0.14**	**0.12**	**1.48**	**10.36**	**39.57**	**0.50**
STDEV				**0.39**	**0.36**	**2.63**	**0.04**	**0.35**	**0.49**	**0.46**	**0.03**	**0.02**	**0.09**	**0.78**	**7.52**	**0.03**
CV				**7.57**	**8.06**	**21.25**	**42.54**	**33.65**	**19.74**	**33.42**	**22.51**	**20.41**	**6.14**	**7.48**	**19.00**	**6.06**

CV = Coefficient of variation, CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability.

Soil Fertility Status of the Site for Crop Production

The soil acidity of the study site ranged between strong (5.26-5.47) and moderate (5.53-5.93) (Table 5). The pH varied minimally (CV <15 %) across the mapping units. The acidic nature of the sub-surface soils of the site is consequent upon the nature of the parent material (Nnaji *et al*., 2002). About 40 %, covering 8.02 ha of the site, was under strongly acidic conditions, while the remaining 60 % (12.04) was moderately acidic (Figure 3). The slight increase in pH values in some portions of the site may be consequent upon higher vegetal cover, resulting in the release of exchangeable bases from decomposed litters and roots (Alemayeha and Sheleme, 2013).

Total nitrogen values (Figure 4) were low (< 0.15 %), covering about 16.06 ha (80 %) of the study site, while 4.0 ha (20 %) was moderate (0.15 – 0.25). The larger portion of the study site (16.06 ha) under the influence of nitrogen deficits may be attributed to volatilization, especially under high-temperature regimes and denitrification processes. Organic carbon contents (Figure 5) were moderate (1.0-1.5 %) in about 16.00 ha (80 %) across the study site, whereas the remaining 4.06 ha (20 %) was relatively high (1.5 – 1.81 %). The few portions of the site that recorded organic carbon slightly above the critical values were attributed to the fact that the study site was still under fallow. However, there is a high rate of decomposition and mineralization of organic matter, which is consequent upon the prevalent high temperature and poor soil management, sometimes by burning crop residues, intense cultivation, and seasonal bush burning, a common practice in the area. Therefore, there is a need for the farmers in the area to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc, that will encourage the return and incorporation of plant/crop residues into the soil to increase the level of soil organic matter.

The exchangeable bases (Ca2+, Na+, and K+) were generally low across the site except for exchangeable Mg2+(Table 5). The low values of exchangeable bases in the study area may be connected to the soils' low CEC values; available P in the soils was moderate (15.10 – 18.40 mg/kg). Base saturation, which provides an indication of how closely nutrient status approaches potential fertility in the soil, was generally low across the site. This may be a result of the area's type and low clay particle size fraction, indicating potential challenges in soil fertility.

CONCLUSION AND RECOMMENDATIONS

The study inventoried the soils of Okporuzor community farmland in Umuahia North LGA of Abia State and assessed the fertility mapping of the soil for site-specific soil management. The findings, which revealed variations in soil properties studied, such as soil texture, organic carbon and exchangeable bases across the study site, are crucial for understanding and improving the soil conditions. The soil was classified as Haplic Kandiudults (USDA) and Haplic Acrisols (WRB). Topsoil fertility mapping showed strong acidity covering about 60% of the land area, moderate organic carbon (80% of the area) and low total N (80% of the area). The site was also low in exchangeable Ca (100% area) and K (100% area) but medium in Mg (100% area) and available Phosphorous (100% area).

Despite the challenges posed by the highly acidic soils, their low nutrient content, and high sand fractions, there is hope for improvement. By implementing specific soil management practices such as liming, the incorporation of organic residues, and the efficient use of fertilizers, the soil conditions can be significantly enhanced. The findings highlight the potential benefits of having local-scale-specific soil information, which can assist in the site-specific application of soil nutrients and amendments based on spatial variability tailored to the soil requiremen

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Table 5: Fertility Status of the Soils of the Study Site

Sample	Sand	Silt	Clay	T/C	pH	Av. P	TN	OC	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	EA	CEC	BS	Al^{3+}
			%		H_2O	mg/kg	%	%		cmol/kg					%	
1	71.20	13.40	15.40	SL	5.32	15.60	0.15	1.62	4.20	1.82	0.15	0.15	1.34	13.41	46.98	0.46
2	73.20	12.40	14.40	SL	5.69	15.10	0.14	1.40	3.62	1.84	0.15	0.15	1.36	12.31	46.79	0.46
3	72.20	11.40	14.40	SL	5.41	15.40	0.13	1.58	3.71	1.91	0.16	0.16	1.38	9.97	59.58	0.47
4	71.20	11.40	17.40	SL	5.46	15.10	0.16	1.55	4.02	1.85	0.15	0.15	1.42	11.37	54.27	0.44
5	55.20	20.40	24.40	SCL	5.82	18.00	0.14	1.40	2.95	2.13	0.22	0.17	1.26	13.01	42.04	0.42
6	66.20	17.40	16.40	SL	5.56	18.30	0.14	1.51	3.73	2.04	0.21	0.17	1.26	13.54	45.42	0.42
7	62.20	16.40	21.40	SCL	5.67	17.80	0.16	1.58	4.15	1.73	0.16	0.14	1.40	11.72	52.73	0.44
8	59.20	17.40	23.40	SCL	5.55	17.20	0.14	1.38	3.48	1.65	0.15	0.15	1.34	10.51	51.67	0.42
9	75.20	13.40	11.40	SL	5.65	17.50	0.13	1.36	4.00	1.72	0.17	0.15	1.32	12.05	50.12	0.44
10	72.20	14.40	13.40	SL	5.93	18.40	0.17	1.81	3.81	1.63	0.16	0.15	1.26	12.33	46.63	0.42
11	73.20	12.30	14.40	SL	5.62	16.70	0.16	1.51	4.23	1.71	0.15	0.16	1.42	10.87	57.50	0.43
12	74.20	13.40	12.40	SL	5.53	17.10	0.13	1.46	3.19	1.85	0.15	0.15	1.34	12.32	43.34	0.45
13	53.20	12.40	34.40	SCL	5.26	16.70	0.11	1.13	3.62	1.76	0.18	0.16	1.40	13.31	42.98	0.48
14	61.20	16.40	22.40	SCL	5.47	17.60	0.14	1.47	3.70	2.04	0.17	0.16	1.38	13.76	44.11	0.46
15	55.20	12.40	32.40	SCL	5.44	17.10	0.13	1.38	3.54	1.81	0.15	0.15	0.36	12.22	46.24	0.46
16	58.20	15.40	26.40	SCL	5.37	16.20	0.14	1.40	3.72	2.15	0.22	0.17	1.26	11.65	53.73	0.43
MEAN	**65.83**	**14.39**	**19.65**		**5.55**	**16.86**	**0.14**	**1.47**	**3.73**	**1.85**	**0.17**	**0.16**	**1.28**	**12.15**	**49.01**	**0.44**
STDEV	**7.86**	**2.59**	**7.07**		**0.18**	**1.10**	**0.02**	**0.15**	**0.35**	**0.16**	**0.03**	**0.01**	**0.25**	**1.11**	**5.37**	**0.02**
CV	**11.95**	**17.97**	**35.96**		**3.23**	**6.54**	**11.94**	**10.09**	**9.38**	**8.75**	**15.13**	**5.73**	**19.69**	**9.12**	**10.95**	**4.42**

Key: T/C = Textural class; OC = Organic carbon; TN = Total nitrogen; Av. P = Available phosphorus; EA = Exchangeable acidity; CEC = cation exchange capacity; BS = Base saturation.

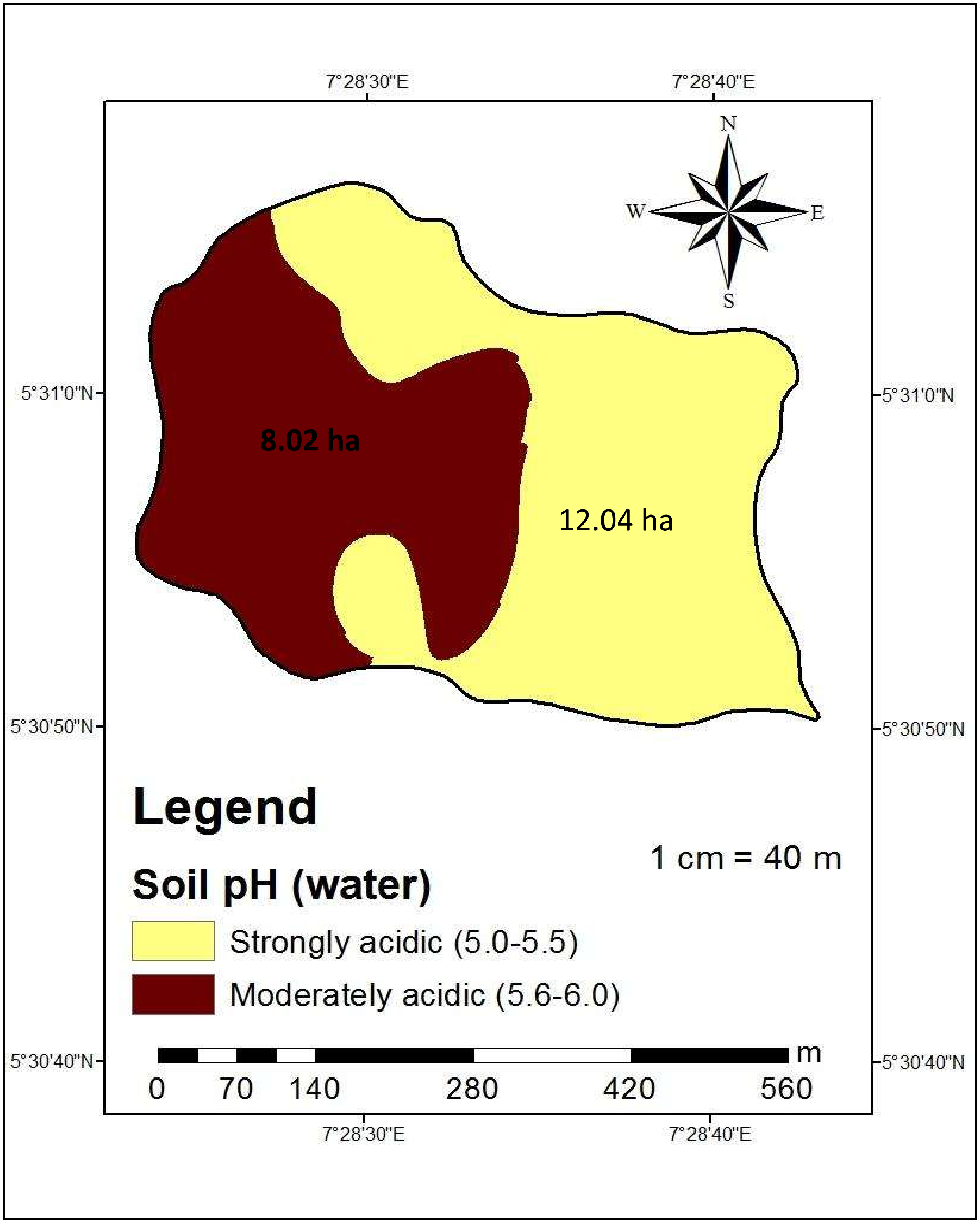

Figure 3: Spatial distribution of pH in the soils of the study site

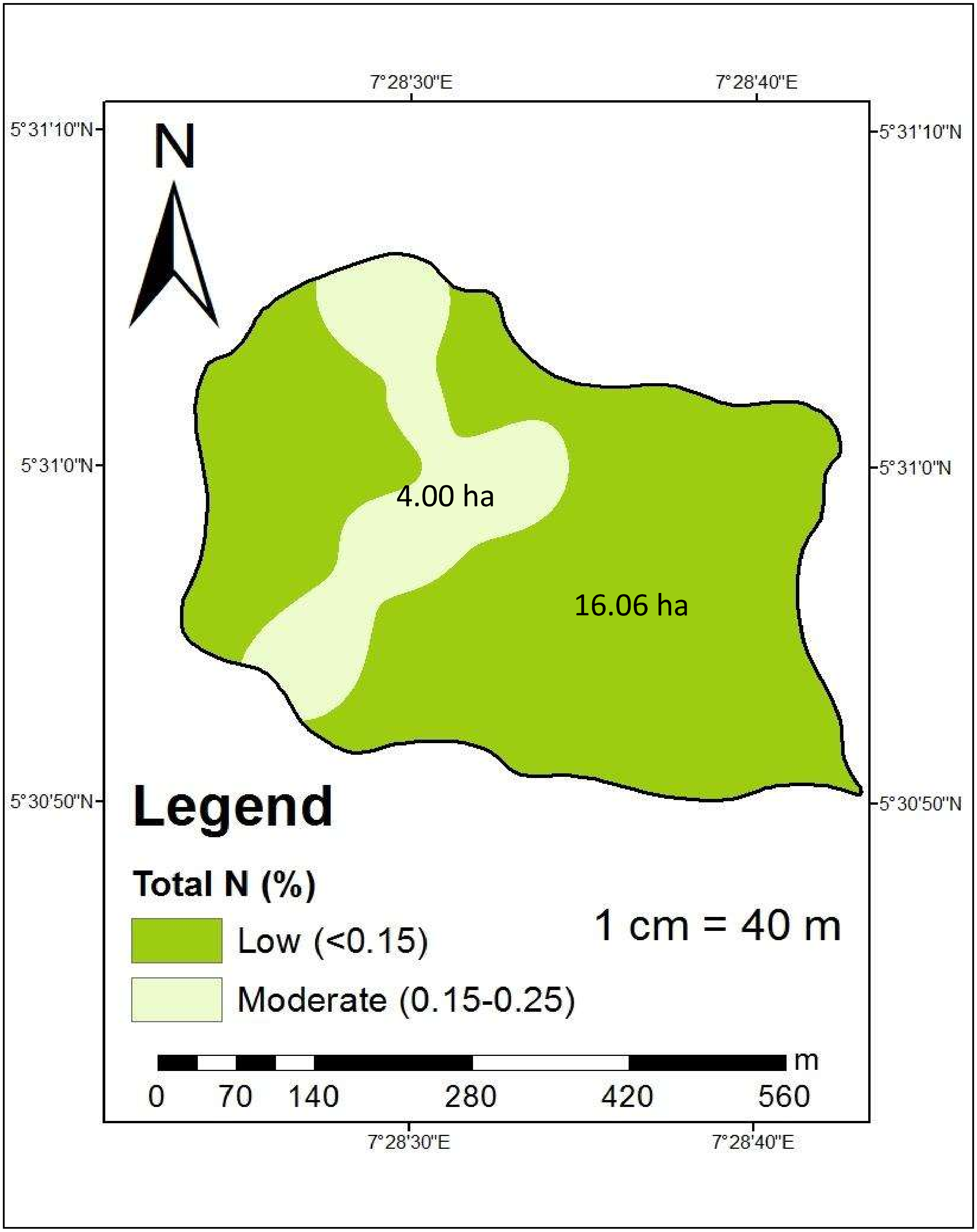

Figure 4: Spatial distribution of total nitrogen in the soils of the study site

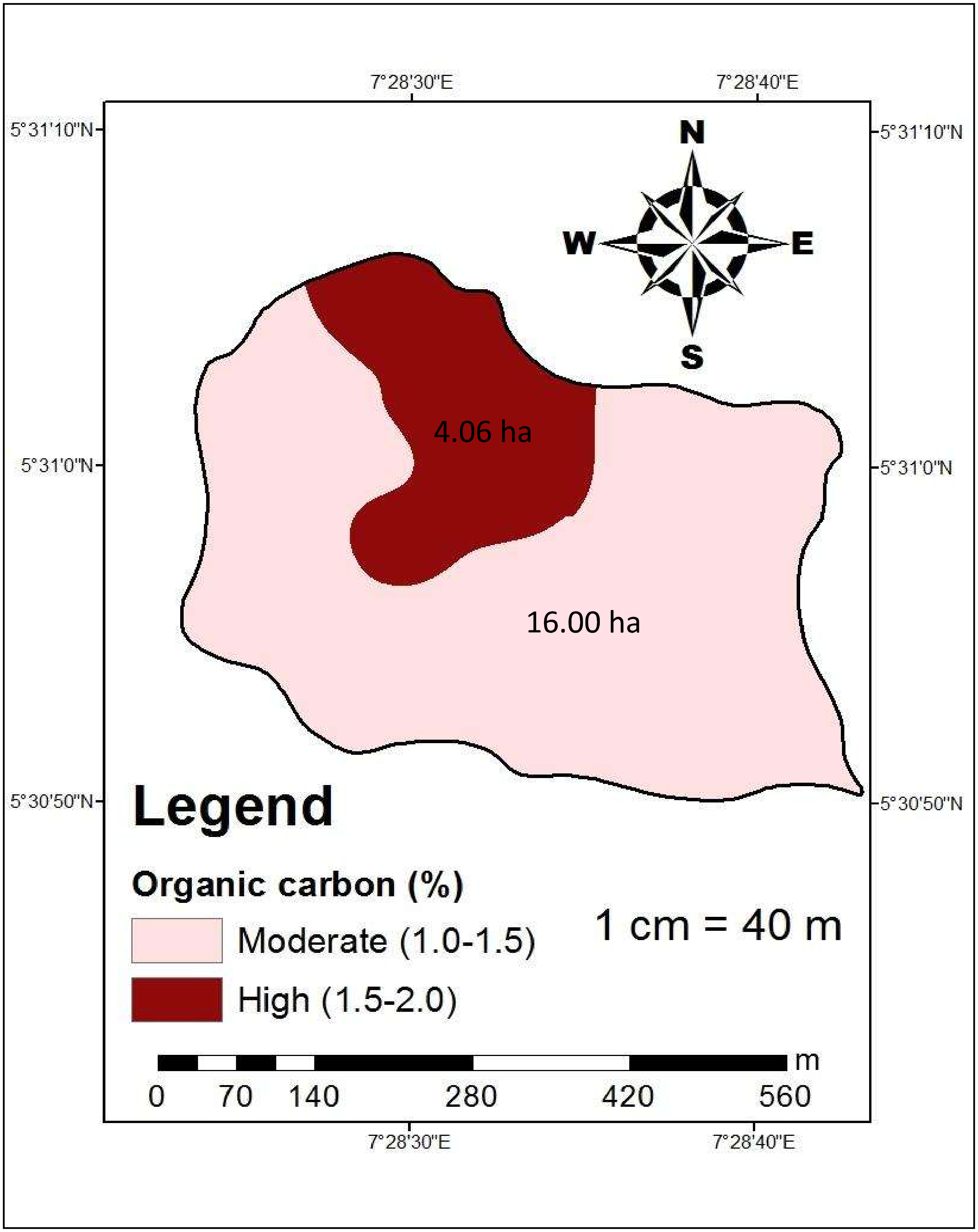

Figure 5: Organic carbon distribution in the soils of the study site

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