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Physio-morphological Characteristics of Soil of Akure, Ondo State SW, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author BFD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BSE and MAA managed the analyses of the study. Authors SOA and TDA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Soil physical properties influence soil water infiltration rate, plant rooting depth, amount of available water, air and nutrients which are of utmost importance in agricultural production and, hence there is need to describe in-situ spatial organization and physical properties of soil in Akure. Sixteen profile pits were dug. The soils were characterized and described on the field and samples collected for textural analysis. The area occurs on level plain with little slope gradient, the surface horizons (A_1 and A_2) were weak medium crumby to moderate medium crumby structures while the subsurface horizons (Bt_1 and Bt_2) showed moderate medium blocky structure. The soils are generally deep and well drained at the top soil with coarse texture; the subsoils are characterized by prominent presence of mottles, which suggest that the subsoils are poorly drained. The distribution of clay content increased with soil depth for all pedons. Most of the Pedons had reddish gray colour (2.5YR 4/1) and dull reddish brown 2.5YR 4/3 at the surface horizons (A_1 and A_2), over brownish colour (7.5YR 4/4) and dull reddish brown (5YR 4/4) sub soil. The particle size distribution revealed that sand dominated the particle size fraction of the soil in all the profiles, which could be managed with appropriate organic manure.

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Keywords: Akure; soil morphology; physical properties; nutrients mapping; horizon; pedon.

1. INTRODUCTION

Research on Akure soil dynamics in relation to agricultural development is scanty. Akure has two local government areas North and South. Agricultural land is becoming a scarce resource in Akure due to massive demographic pressure growing rapidly owing to favourable socio-economic, political, and physical factors. [1] has described the resultant changes in soil nutrients, morphology and physical parameters. This information of land evaluation is essential for determining the origin and fertility of the soils and its distribution in the study area. The result of the study provided updated information on study area using spatial analysis, detailed digital soil maps, data tables and text narratives could be used in land planning programs.

2. METHODOLOGY

2.1 Description of the Study Area

The study was carried out in both Akure North and Akure South Local Government Areas of Ondo State. The areas are agrarian communities located in tropic rainforest zone in Nigeria. The citizens are predominantly farmers and Akure is the trade center for a farming region where cocoa, yams, cassava, and corn are grown. The locations lie within latitude 7°09' and 7°19'N and longitudes 5°07' and 5°17'E.

2.2 Topography

The metropolis is located on a gentle undulating terrain surrounded by isolated hills and inselbergs. Topographic elevations vary between 260 and 470 m above sea level [2].

2.3 Climate and Rainfall

The climate of the study areas is hot and humid, influenced by rain bearing Southwest Monsoon winds from the ocean and dry Northwest winds from the Sahara desert. The raining season lasts from April to October with rainfall of about 1524 mm annually. Temperatures vary from 28°C to 31°C with mean annual relative humidity of about 80(%).

2.4 Field Studies and Sampling Techniques

The study was carried out in Akure North and South L.G.A of Ondo State. The sites were divided into Map Grids and pedons established within the grids. Sixteen pedons (1.5 m wide x 1.0 m long x 1.5 m deep) were established. The pedon locations were geo-referenced with Global Positioning System (GPS) (Table 1). Horizons were designated and morphological description carried out on the field in moist condition using Munsell Soil Colour Charts. 500 g soil representative samples were collected from each of the designated horizon. They were packed in polythene bags, neatly labelled and taken to the laboratory for physical and chemical analysis. The soil samples were air dried, gently ground in a mortar and sieved with a 2 mm sieve. Particle size distributions were determined by hydrometer method [3]. Soil pH was determined using a glass electrode in 1:2 soil: water ratio [4] (Thomas, 1996). Soil organic carbon (O.C) was determined using Walkley and Black method and organic matter estimated by multiplying with a factor of 1.724 as was done by [5]. Total Nitrogen was determined by Kjeldahl digestion procedure [6]. Available phosphorus was determined using the Bray-P method and exchangeable acidity by KCl extraction method [7]. Exchangeable bases (Ca, Mg, Na and K) were extracted by leaching with 1N NH4OAC (pH 7.0). Ca and Mg were determined by Atomic absorption spectrophotometer. GIS of the study area and remote sensing were developed with ARC GIS 10.3 and soil positioning taken by Land meter NF-198. The images were enhanced, geo-referenced, classified and digitized.

2.5 Laboratory Analysis

The soil samples collected were analysed using standard procedures. All the soil samples were air-dried and then sieved using a 2 mm sieve and particle sizes larger than 2 mm were weighed as gravel. Those that were less than 2 mm were used for laboratory analysis and particle size distribution of the soils were determined by the method of [7] and hydrometer method described by [8]. Soil bulk density was determined as per [9].

3. RESULTS

3.1 Pedon 1 (Igoba)

The Pedon was located on nearly level plain with slope gradient 0-2 (%) with elevation 356 above sea level. It was well drained and deep (120cm); colour matrix of the epipedon ranged from dark

brown (7.5YR 3/4) to bright brown (7.5YR 6/8) while the epipedon exhibited orange colour matrix (2.5YR 6/8); prominent mottling colour was brown (2.5YR 3/6) at Btg2 horizon. The top soil (A_1) exhibited moderate medium crumby structure while subsurface has strong fine blocky structure. Consistence showed firm in the surface horizon while the endopedons were very firm. Fine, medium to very few root concentration was observed in the top soil.

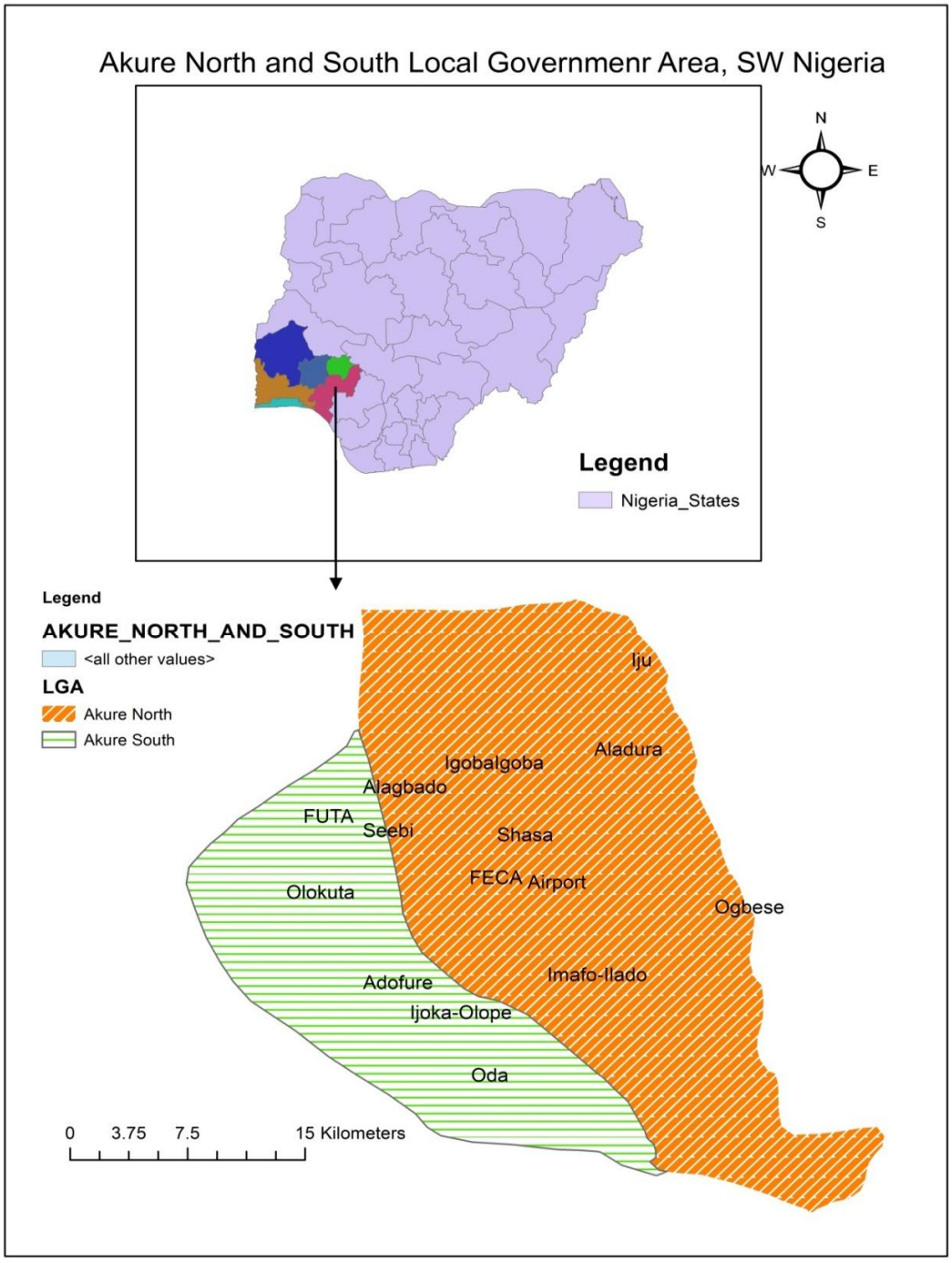

Fig. 1. Map of Akure south and north local government area of Ondo State showing locations of profile pits dug

Table 1. GPS readings of pedons sites

Pedon	Sites	Longitude (E)	Latitude (N)	Elevation
1	Igoba	5.25148	7.33326	351
2	Saasa	5.25306	7.2902	347
3	Airport	5.27067	7.262	323
4	Oda	5.23815	7.14666	329
5	Imafo-Ilado	5.28192	7.20673	327
6	Iju	5.33001	7.39464	332
7	Ogbese	5.370401	7.25791	309
8	Eleyo-owo	5.28757	7.27274	336
9	Aladura	5.30886	7.34136	330
10	Alagbado	5.17608	7.31883	406
11	Adofure	5.17634	7.20205	356
12	Olokuta	5.13219	7.25593	354
13	FECA	5.23733	7.26462	347
14	Seebi	5.176	7.29286	377
15	FUTA	5.14194	7.30134	375
16	Ijoka Olope	5.20312	7.18417	345

3.2 Pedon 2 (Saasa)

Pedon 2 was formed on a convex topography with a slope gradient of 0-2(%) and an elevation of 351 m above sea level. The pedon was well drained and deep 130cm. The surface horizons were dark brown (7.5YR 3/4) at A_1 horizon and bright brown (7.5YR 5/6) at Bt_1 horizon while Btg2 exhibited orange colour (2.5YR 6/8) at the endopedon. The pedon had moderate medium crumby structure from the surface horizon while the successive horizons (Bt_1 and Bt_{g2}) had moderate medium blocky and strong fine blocky structure respectively. Consistence was firm in the surface horizon while the endopedon was very firm.

3.3 Pedon 3 (Airport)

Pedon 3 was poorly drained and not deep well. It occurred on nearly plain landscape with a slope gradient of 0-2(%) and an elevation of 350 m above sea level. The pedon exhibited dark brown (5YR 3/4) endopedon. Colour mottling is brown. The surface horizon was strong and very coarse while the endopedon exhibited strong coarse crumby structure. Consistence ranged from very friable, friable to fine firm at the surface. Root was frequent at the surface horizon.

3.4 Pedon 4 (Oda)

Pedon 4 occurred at 331 m above sea level, an almost flat terrain with 0-2 (%) slope gradient. The pedon was well drained and deep (150 cm). The surface horizons of the pedon ranged from reddish gray to dull reddish brown (2.5YR 4/1 to 2.5YR 4/3) while the subsurface horizons ranged from brown colur to dull reddish brown (7.5YR 4/4 – 5YR 4/4. Mottling colour at endopedon was yellow to orange (7.5 YR -7/8 YR). The top soil (A_1 and A_2) exhibited weak to moderate medium crumby structure whereas, the sub soil was moderate medium blocky with friable consistence (A_1 and A_2) at the surface whereas it was firm at subsurface. Roots concentrated was high at A_1 and A_2 horizons.

3.5 Pedon 5 (Imafo-Ilado)

Pedon 5 was formed on valley bottom topography, with a slope gradient of 0-2 (%) with an elevation of 323 m; the horizon colour was dark brown (7.5YR 3/4) and A_2 was bright reddish brown (5YR 5/6). The highest sand percentage was obtained at A_1 and A_2 horizon 50 (%) each) while clay percentage was the highest at Btg2 horizon. Gravel content was the highest at Btg2 horizon with 204 g. Horizon Bt_1 and Btg2 have the highest bulk density of 1.25 g/cm. Soil textures are Sandy Loam (SL) and Clay Loam (CL).

3.6 Pedon 6 (Iju)

Pedon 6 on the landscape was nearly level plain with a slope gradient of (0 – 2 (%) and an elevation of 333.9 m above sea level. The soil was deep and well drained with no encounter to water table and impenetrable layer at the depth

of 120 cm. The surface horizons (A1 and A2) were light gray (2.5Y 7/2) and greyish brown (10YR 4/3) underlain by reddish yellow (7.5YR 6/6 – 2.5YR 4/6) endopedon with light red colour (7.5R 6/6 - 2.5YR 7/8) mottles. The surface horizon (A1) exhibited moderate coarse crumb structure and in (A2) there was no observable degree of aggregation (structureless), whereas in the subsoil (Btg1 and Btg2), the structure was moderately blocky. The physical condition of the soil to manipulations (consistence) at the horizons were friable at the topsoil (A1) to firm subsoil (A2, Btg1 and Btg2). No concretions were observed. Common medium and fine roots concentrated in the upper 40 cm of the surface horizons.

3.7 Pedon 7 (Ogbese)

Pedon 7 occurred on 309.5 m above sea level, almost flat terrain with 0 -2(%) slope gradient. The pedon was well drained but poorly drained at the epipedon. The surface horizons of the pedon was reddish gray (5R 5/1) underlain by light gray and light brownish gray (10YR 7/2 – 10YR 6/4) and red colour mottles (2.5YR3/6) in the subsoil. The top soil (A1) exhibited moderate medium crumb structure to a depth of 60 cm whereas, the subsoil (Bt1 and Btg2) was moderate medium blocky crumb and strong fine sub angular blocky crumbs respectively and Consistence varied from firm surface horizon to very firm subsurface horizons with common medium fine to few roots concentrated in the upper 30 cm of the soil surface and very fine very few roots at the sub horizons.

3.8 Pedon 8 (Eleyo-owo)

Pedon 8 was well drained and deep with slope gradient of 0- 2(%) with an elevation of 336 m above sea level. The colour matrix ranged from dark reddish brown (2.5YR 3/4) A1, red colour matrix (2.5YR 5/6) at Bt1 and strong brown (7.5YR 4/6) subsoil with (2.5YR 3/6) dark reddish colour mottles at the last horizon. The pedon had moderate medium crumb structure from the surface horizon to 30 cm depth while the successive horizons (Bt1 and Btg2) were moderate blocky and fine strong blocky. Consistence condition revealed firm at the surface horizon and very firm subsurface horizon. Presence of root at the upper 30 cm was fine medium to a few roots and very fine and very few roots at the sub horizons (30-90 cm). There was no root at the last horizon Btg2.

3.9 Pedon 9 (Aladura)

Pedon 9 was located on nearly level plain with slope gradient 0-2(%) with elevation of 304 m above sea level. It was well drained and deep (> 105 cm). Colour matrix varied from dark brown (7.5YR 3/4) epipedon to reddish yellow (7.5YR6/8) endopedon. The pedon had moderate medium crumb structure in the epipedon and moderate medium blocky structure in the subsoil. Consistence was firm at the epipedon and very firm at the endopedon. Common to medium roots concentrated found at A1 and A2.

3.10 Pedon 10 (Alagbado)

The results of the morphological properties of the soil of the study area are shown in Table 1. The position of pedon 10 on the landscape was nearly level plain with a slope gradient of 0-2 (%) and an elevation 393 m above sea level. The soil was deep and well drained. The surface horizon (A_1 and A_2) were brownish black (10YR 2/2) and dull reddish brown (5YR 4/3) underlain by brown colour (2.5YR 4/8). The subsurface horizons (Bt_2 and Bt_3) exhibited some mottling characteristics with both having 2.5Y 7/8. The surface horizons exhibited moderate crumbly structure from the surface horizon while the successive horizons (Bt_g2 and Btg3) are blocky, consistence was friable in the surface horizon while the endopedons were firm, very few root concentrated in the upper surface of the pedon. The vegetation of the area is mainly elephant grass, sunflower etc.

3.11 Pedon 11 (Adofure)

The profile was well drained and deep. It occurred on nearly level plain landscape with a slope gradient of 0.2(%) and an elevation of 375 m above sea level. The pedon exhibited dark colour (2.5YR 3/2 – 10R 5/6) (A_1 and A_2) over red coloured (10R 5/6 – 10R 5/8) endopedon. The surface horizons had weak fine crumby structure while the endopedon exhibited moderate medium angular blocky structure. Consistence varied from very friable to friable at the surface horizons while it varied from firm to very firm at the subsurface horizons, root was firm and common on the surface horizon (A_1 and A_2) while the subsurface horizons were firm and the few common vegetation found is *Titonia dyfasiftolia*.

Table 2. Akure North L.G.A: Soil morphology properties of pedon 1-5

Pedon	Horizon	Depth(cm)	Colour(Moist)	Mottles	Drainage	Slope (%)	Structure	Consistence	Root	Boundary
1	**Igoba**									
	A1	0-26	7.5YR ¾	Absent	Good	0-2	2.cr.m	Fm	f.cm	d, g
	A2	26-47	7.5YR 4/5	Absent	Good		2.cr.m	Fm	f-m.fw	s, h
	Bt1	47-90	7.5YR 5/6	Absent	Good		2.bk.m	Vfm	vf.vfw	a, s
	Btg2	90-120	2.5YR 6/4	2.5YR 3/6	Good		3.bk.f	Vfm	Absent	a, s
2	**Saasa**									
	A1	0-30	7.5YR ¾	-	Good	0-2	2.cr.m	Fm	f-m.fw	c, s
	Btg1	30-70	7.5YR 5/6	-	Good		2.bk.m	Vfm	vf.vfw	a, s
	Btg2	70-130	2.5YR 6/8	2.5YR 3/6	Good		3.bk.f	Vfm	-	c, s
3	**Airport**									
	A1	0-30	5YR 3/2		Good	0-2	3.vc	vfr-fr	vf-c. fq-a	d, g
	Btg1	30-70	5YR 3/4	10YR 6/8	Good		3.cr.c	f.fm	-	s, h
4	**Oda**									
	A1	0-30	2.5YR 4/1	-	Good	0-2	1.cr.m	Fr	f-m.cm	a, s
	A2	30-70	2.5YR 4/3	-	Good		2.cr.m	Fr	f.vfw	d, w
	Btg1	70-100	7.5YR 4/4	-	Good		2.bk.m	Fm	Vf.vfw	a, s
	Btg2	100-150	5YR 4/4	7.5YR 7/8	Good		2.bk.c	Fm	-	
5	**Imafollado**									
	A1	0-25	7.5YR ¾	-	Good	0-2	1.cr.m	Fr	Fr	d, g
	A2	25-70	5YR 5/6	-	Good		2.cr.m	Fr	Fm	s, h
	Btg1	70-100	2.5YR 4/8	-	Good		2.bk.m	Fm	f-m.fw	a, s
	Btg2	100-150	2R 7/1	-	Good		2.bk.c	Fm	f.cm	d, g

Key: Structure: 1 = Weak, 2 = Moderate, 3 = Strong, M = Medium, C = Coarse, F = Fine, Cr = Crumb, Sbk = Sub-angular blocky. Consistence: s = soft, l = loose, sh = slightly hard, h = hard, vh = very hard, fr = friable, fm = firm, vfm = very firm, ns-np = non sticky-non plastic, s-sp = slightly sticky-slightly plastic, s-p = sticky-plastic. Roots: cc = common coarse, cm = common medium, fm = few medium, cf = common fine, ff = few fine Boundary: a = abrupt, c = clear, g = gradual, w = wavy, s = smooth, h = sharp, d = diffused

Table 3. Akure North L.G.A: Soil morphology properties of pedons 6-9

Pedon	Horizon	Depth(cm)	Colour(Moist)	Mottles	Drainage	Slope (%)	Structure	Consistence	Root	Boundary
6	**Iju**									
	A1	0-23	2.5Y 7/2	Absent	Good	0 -2	2,Cr.m	Fr	cm	c, s
	A2	23-40	10YR 4/3	Absent	Good		0	Fm	f.cm	g, w
	Btg1	40-75	7.5YR 6/6	7.5R 6/6	Good		2.bk	Fm	ff	a, s
	Btg2	75-120	2.5YR 4/6	2.5YR 7/8	Good		2.bk	Fm	vff	-
7	**Ogbese**									
	A1	0-20	5R 5/1	Absent	Good	0-3	2.cr.m	Fm	f-m.fw	a, s
	Bt1	20-60	10YR 7/2	Absent	Poor		2.bk.m	Vfm	vf.vfw	d, w
	Btg2	60-100	10YR 6/8	2.5YR 3/6	Poor		3.sbk.f	Vfm	Absent	a, s
8	**Eleyowo**									
	A1	0-30	2.5YR ¾	Absent	Good	0 – 2	2.cr.m	Fm	f-m.fw	c, s
	Bt1	30-90	2.5YR 5/6	Absent	Good		2.bk.m	Vfm	vf.vfw	c, s
	Btg2	90-120	7.5YR 4/6	2.5YR 3/6	Good		2.bk.f	Vfm	Absent	a, s
9	**Aladura**									
	A1	0-30	7.5YR ¾	Absent	Good	0 -2	2.cr.m	Fm	f-m.cm	c, s
	A2	30-70	7.5 YR 7/2	Absent	Good		2.cr.m	Fm	f-m.fw	g, w
	Bt1	70- 105	7.5YR 6/8	Absent	Good		2.bk.m	Vfm	vf.vfw	a, s

Key: Structure: 1 = Weak, 2 = Moderate, 3 = Strong, M = Medium, C = Coarse, F = Fine, Cr = Crumb, Sbk = Sub-angular blocky. Consistence: s = soft, l = loose, sh = slightly hard, h = hard, vh = very hard, fr = friable, fm = firm, vfm = very firm, ns-np = non sticky-non plastic, s-sp = slightly sticky-slightly plastic, s-p = sticky-plastic. Roots: cc = common coarse, cm = common medium, fm = few medium, cf = common fine, ff = few fine Boundary: a = abrupt, c = clear, g = gradual, w = wavy, s = smooth, h = sharp, d = diffused

Table 4. Akure South LGA: Soil morphology properties. Pedons 10-13

Pedon		Horizon	Depth(cm)	Colour	Mottles	Slope (%)	Drainage	Structure	Consistence	Root	Boundary
10	**Alagbado**										
		A1	0-15	10YR 2/2	Absent	0-5	Good	2.cr.m	Very firm	ff	Cs
		A2	15-30	5YR 4/3	Absent		Good	2.cr.m	Firm	fvf	Cs
		Btg1	30-90	2.5YR 4/8	2.5Y 7/8		Good	2.bk	Firm	a	As
		Btg2	90-150	2.5YR 4/7	2.5YR 7/8		Good	2.bk	Firm	a	cs
11	**Adofure**										
		A1	0-20	2.5YR 3/2	Absent	0-2	Good	1.cr.f	Friable	cf	As
		A2	20-30	10R 5/6	Absent		Good	1.cr.f	Firm	fc	Cs
		Btg1	30-90	10R5/8	10YR 6/8		Good	2.abk.m	Firm	ff	Cs
		Btg2	90-150	2.5YR 4/8	10YR 6/8		Good	2.bk.m	Firm	a	Cs
12	**Olokuta**										
		A1	0-20	2.5YR 3/2	Absent	7-13	Good	1.cr.f	Firm	ff	Cs
		A2	20-30	10R 5/6	Absent		Good	1.cr.f	Firm	fvf	Cs
		Btg1	30-90	10R5/8	10YR 6/8		Good	2.abk.m	firm	a	Cw
		Btg2	90-150	2.5YR 4/8	10YR 6/8		Good	2.bk.m	Very firm	a	Cs
13	**FECA**										
		A1	0-30	2.5YR 4/1	Absent	0-2	Good	1.cr.m	Firm	ff	Cs
		A2	30-70	2.5YR 4/3	Absent		Good	2.cr.m	Very firm	mf	cs
		Btg1	70-100	7.5YR 4/4	Absent		Good	2.bk.m	Very firm	f	cw
		Btg2	100-150	5YR 4/4	7.5YR 7/8		Good	2.bk.c		a	cs

KEY: Structure: 1 = Weak, 2 = Moderate, 3 = Strong, M = Medium, C = Coarse, F = Fine, Cr = Crumb, Sbk = Sub-angular blocky. Consistence: s = soft, l = loose, sh = slightly hard, h = hard, vh = very hard, fr = friable, fm = firm, vfm = very firm, ns-np = non sticky-non plastic, s-sp = slightly sticky-slightly plastic, s-p = sticky-plastic. Roots: cc = common coarse, cm = common medium, fm = few medium, cf = common fine, ff = few fine Boundary: a = abrupt, c = clear, g = gradual, w = wavy, s = smooth, h = sharp, d = diffused

Table 5. Akure South LGA: Soil morphology properties. Pedon 14-16

Pedon		Horizon	Depth(cm)	Colour	Mottles	Slope (%)	Drainage	Structure	Consistence	Root	Boundary
14	**Seebi**										
		A1	0-30	2.5YR 4/1	Absent	5-7	Good	1.cr.m	Friable	cf	cs
		A2	30-70	2.5YR 4/3	Absent		Good	2.cr.m	Friable	cf	as
		Btg1	70-100	7.5YR 4/4	7.5YR 7/8		Good	2.bk.m	Very firm	mf	cs
		Btg2	100-150	5YR 4/4	7.5YR 7/8		Good	2.bk.c	Very firm	a	cs
15	**FUTA**										
		A1	0-30	2.5YR 4/1	Absent		Good	1.cr.m	Friable	ff	cs
		A2	30-70	2.5YR 4/3	Absent	0-2	Good	2.cr.m	Friable	cf	cs
		Btg1	70-120	7.5YR 4/4	Absent		Good	2.bk.m	Firm	a	cs
		Btg2	120-150	5YR 4/4	7.5YR 7/8		Good	2.bk.c	Firm	a	as
16	**Ijoka-Olope**										
		A1	0-15	7.5YR ¾	Absent	0-2	Good	2.cr.m	Friable	ff	cs
		A2	15-35	5YR 5/6	Absent		Good	2.bk.m	Firm	ff	cs
		Btg2	35-90	5YR 4/4	7.5YR 7/8		Good	3.abk.c	Very firm	mf	cs
		Btg2	90-150	2.5YR 4/8	10YR 6/8		Good	2.bk.m	Very firm	a	as

KEY: Structure: 1 = Weak, 2 = Moderate, 3 = Strong, M = Medium, C = Coarse, F = Fine, Cr = Crumb, Sbk = Sub-angular blocky. Consistence: s = soft, l = loose, sh = slightly hard, h = hard, vh = very hard, fr = friable, fm = firm, vfm = very firm, ns-np = non sticky-non plastic, s-sp = slightly sticky-slightly plastic, s-p = sticky-plastic. Roots: cc = common coarse, cm = common medium, fm = few medium, cf = common fine, ff = few fine Boundary: a = abrupt, c = clear, g = gradual, w = wavy, s = smooth, h = sharp, d = diffused

3.12 Pedon 12 (Olokuta)

Pedon 12 Occurred on 354 m above sea level, almost flat terrain with 0.2(%) slope gradient. The pedon was well drained and deep (150 cm). The surface horizons of the pedon were dark to red colour (2.5YR 3/2 – 10R 5/6) underlain by red colour (10R 5/6 – 2.5YR 4/8) subsoil. The top soil (A_1 and A_2) exhibited weak fine crumby structure while the subsoil exhibited moderate medium angular blocky structure. Consistence varied from very friable to friable at the surface horizons while it varied from firm to very firm at the subsurface horizon. Root was common at the surface but very few at subsurface. Cocoa, banana, yam, oil palm, pawpaw, coconut and mango were the common vegetation.

3.13 Pedon 13 (FECA)

Pedon 13 was located on a plain topography with a slope gradient of 0-2(%) and elevation of 375 m above sea level; it was well drained and deep (150cm). the pedon had reddish gray colour (2.5YR 4/1) and dull reddish brown 2.5YR 4/3 at the surface horizons (A_1 and A_2) over brownish colour (7.5YR 4/4) and dull reddish brown (5YR 4/4) sub soil. It was characterized with yellow orange 7.5YR 7/8 mottles. The surface horizons (A_1 and A_2) were weak to moderate medium crumby structure while subsurface horizons (Bt_1 and Bt_2) showed moderate medium blocky temperature. Consistence was friable in the surface horizon while the endopedons were firm. There were firm, medium and common root concentrations in the top soil.

3.14 Pedon 14 (Seebi)

Pedon 14 occurred on an almost flat terrain with 2.6(%) slope gradient and an elevation of 388 m above sea level. The pedon was drained and deep (150cm). The colour matrix of the epipedon ranged from red dish gray (2.5YR 4/1) to dull reddish brown (2.5YR 4/3) while endopedon exhibited brown (7.5YR 4/4) to dull reddish brown (5YR 4/4), prominent mottling colour was yellow orange (7.5YR 7/8).

3.15 Pedon 15 (FUTA)

The surface horizons (A_1 and A_2) of pedon 15 were weak medium crumby to moderate medium crumby structure while the subsurface horizons (Bt_1 and Bt_2) showed moderate medium blocky structure. Consistence varied from friable to firm in all the horizons. A few medium to common root concentrations were in the top soil. Pedon 6 (figure) occurred at 387 m above sea level; almost flat terrain with 0.2 (%) slope gradient. The pedon was well drained and deep (150 cm). The surface horizons were reddish gray (2.5YR 4/1) to dull reddish brown (2.5YR 4/3) underlain by brown (7.5YR 4/4) and dull reddish brown (5YR 4/4) subsoil. Mottling colour was yellow orange (7.5YR 7/8). The top soil (A_1 and A_2) exhibited weak to moderate medium crumb structure whereas, the subsoil showed moderate medium blocky structure. Consistence ranged from friable to firm in all the horizons of the pedon. There were fine, medium and common root concentrations.

3.16 Pedon 16 (Ijoka Olope)

The Pedon was located on a plain topography with a slope gradient of 0.2(%) and an elevation of 347 m above sea level. It was well drained and deep (150 cm). The surface horizons of the pedon were bright reddish (5YR 5/6) and dull reddish brown (5YR 4/4) subsurface. Prominent mottling colour was yellow orange (7.5YR 7/8) at Btg_2 horizon. The top soil (A_1) exhibited moderate medium blocky nature while Btg_1 had strong coarse angular blocky structure and the subsoil surface had moderate medium blocky structure. Consistence ranged from firm to very firm throughout the horizons. Fine and very few root concentration observed in the lower surface of the horizon.

4. PHYSICAL PROPERTIES OF SOILS OF AKURE NORTH AND AKURE SOUTH LOCAL GOVERNMENT AREAS OF ONDO STATE

4.1 Pedon 1 (Igoba)

The highest sand (%) was obtained at Bt_1 and Btg2 horizons 66 (%) each while clay (%) was the highest at Bt_1 and Btg2 horizons (25(%) each). Gravel content was the highest at Bt_1 with 192 g. The Btg2 horizon had the highest bulk density of 1.34 g/cm^3. Soil texture was Sandy Clay Loam (SCL).

4.2 Pedon 2 (Saasa)

The highest sand (%) was obtained at A_1 horizon 70 (%) and the clay (%) was the highest at Bt_1 and Btg2 with 30 (%) each. Gravel content was the highest at A_1 horizon with 432 g. The Btg2 horizon had the highest bulk density of 1.31 g/cm^3. Soil textures are Sandy Loam (SL) and Sandy Clay Loam (SCL).

4.3 Pedon 3 (Akure Airport)

The highest sand (%) was obtained at A_1 horizon 64 (%) while Clay (%) was higher at Bt_1 horizon 46 (%). Gravel content was high at A_1 horizon with 432 g. Bulk density was higher at Bt_1 horizon (1.52 g/cm^3). Soil textures are Sandy Loam (SL) and Clay Loam (CL).

4.4 Pedon 4 (Oda)

The highest sand (%) was obtained at A_1, Bt_1 and Btg2 20 (%) each while clay (%) was the highest at A_1 and Bt_1 with 64 (%) each. Gravel content was highest at the A_2 horizon with 190 g. The Btg2 horizon had the highest bulk density of 1.35 g/cm.^{3} Soil texture in all the horizons of the pedon was Sandy Clay (SC).

Table 6. Akure North L.G.A: Soil physical properties pedon 1-7

	Pedon	Horizon	Depth (cm)	Sand ((%))	Silt ((%))	Clay ((%))	Soil Texture	BD (g/cm^3)	Porosity ((%))
1	Igoba								
		A1	0-26	56.00	14.00	30.00	SCL	1.25	44.44
		A2	26-47	50.00	20.00	30.00	SCL	1.25	44.44
		Bt1	47-90	64.00	20.00	16.00	SL	1.28	43.11
		Btg2	90-120	64.00	20.00	16.00	SL	1.31	41.78
2	Saasa								
		A1	0-30	56.00	14.00	30.00	SCL	1.28	43.11
		Bt1	30-70	56.00	14.00	30.00	SCL	1.25	44.44
		Btg2	70-130	50.00	20.00	30.00	SCL	1.28	43.11
3	Airport								
		A1	0-30	64.00	20.00	16.00	SL	1.31	41.78
		Bt1	30-70	40.00	14.00	46.00	CL	1.52	32.44
4	Oda								
		A1	0-30	20.00	16.00	64.00	SC	1.25	44.44
		A2	30-70	20.00	20.00	60.00	SC	1.25	44.44
		Bt1	70-100	16.00	20.00	64.00	SC	1.31	41.78
		Btg2	100-150	20.00	20.00	60.00	SC	1.35	40.00
5	Imafo- Ilado								
		A1	0-25	50.00	10.00	40.00	SL	1.12	50.22
		A2	25-70	50.00	10.00	40.00	SL	1.16	48.44
		Bt1	70-100	30.00	20.00	50.00	CL	1.25	44.44
		Btg2	100-150	30.00	10.00	60.00	CL	1.25	44.44
6	Iju								
		A1	0-23	56.00	14.00	30.00	SCL	1.28	43.11
		A2	23-40	50.00	20.00	30.00	SCL	1.25	44.44
		Btg1	40-75	64.00	20.00	16.00	SL	1.25	44.44
		Btg2	75-120	64.00	20.00	16.00	SL	1.31	41.78
7	Ogbese								
		A1	0-20	56.00	14.00	30.00	SCL	1.25	44.44
		Bt1	20-60	50.00	20.00	30.00	SCL	1.28	43.11
		Btg2	60-100	64.00	20.00	16.00	SL	1.31	41.78
8	Eleyo-owo								
		A1	0-30	50.00	20.00	30.00	SCL	1.12	50.22
		Bt1	30-90	50.00	20.00	30.00	SCL	1.22	45.78
		Btg2	90-120	40.00	30.00	30.00	SCL	1.27	43.56
9	Aladura								
		A1	0-30	56.00	14.00	30.00	SCL	1.25	44.44
		A2	30-70	50.00	20.00	30.00	SCL	1.28	43.11
		Bt1	70- 105	64.00	20.00	16.00	SL	1.36	39.56

BD= Bulk Density

4.5 Pedon 5 (Imafo- Ilado)

The highest sand percentage was obtained at A_1 and A_2 horizons 50 (%) each while clay (%) was the highest at Btg 2 horizon. Gravel content was the highest at Btg2 horizon with 204 g. Horizon Bt_1 and Btg2 had the highest bulk density of 1.25 g/cm. Soil textures were Sandy Loam (SL) and Clay Loam (CL).

4.6 Pedon 6 (Iju)

Btg 1 and Btg 2 had a sand percentage of 64 (%) while clay percentage decreased down the profile from 30(%) at A1 to 16 (%) at Btg2. The soil bulk density also increased down the profile. Porosity increased from down the profile.

4.7 Pedon 7 (Ogbese)

Three horizons were established in Pedon Ogbese. Hardpan was encountered at 1 m down the profile. Percentage of sand increased down the profile while that of clay decreased. Bulk density was 1.25 g/cm^3 at A1 horizons while 1.31 g/cm^3 was observed at Btg2.

Table 7. Akure South L.G.A: Soil physical properties pedons 10-16

Pedon		Horizon	Depth (cm)	Sand ((%))	Silt ((%))	Clay ((%))	Soil Texture	BD (g/cm3)	Porosity ((%))
10	Alagbado								
		A1	0-15	57.00	27.00	16.00	SCL	1.23	45.33
		A2	15-30	69.00	21.00	10.00	SCL	1.29	42.67
		Btg1	30-90	55.00	21.00	24.00	SCL	1.32	41.33
		Btg2	90-150	59.00	15.00	26.00	SL	1.36	39.56
11	Adofure								
		A1	0-20	50.00	10.00	40.00	SL	1.12	50.22
		A2	20-30	50.00	10.00	40.00	SL	1.16	48.44
		Btg1	30-90	30.00	20.00	50.00	CL	1.25	44.44
		Btg2	90-150	30.00	10.00	60.00	CL	1.25	44.44
12	Olokuta								
		A1	0-20	70.00	6.00	24.00	SL	1.11	50.67
		A2	20-30	68.00	14.00	16.00	SL	1.11	50.67
		Btg1	30-90	70.00	10.00	20.00	SL	1.14	49.33
		Btg2	90-150	70.00	10.00	20.00	SL	1.16	48.44
13	FECA								
		A1	0-20	50.00	30.00	20.00	L	1.11	50.67
		A2	20-50	50.00	30.00	20.00	L	1.14	49.33
		Btg1	50-90	60.00	20.00	20.00	SL	1.15	48.89
		Btg2	90-150	60.00	20.00	20.00	SL	1.22	45.78
14	Seebi								
		A1	0-30	70.00	14.00	16.00	SL	1.27	43.56
		A2	30-70	56.00	4.00	40.00	SC	1.34	40.44
		Btg1	70-100	40.00	10.00	50.00	SC	1.43	36.44
		Btg2	100-150	64.00	12.00	24.00	SCL	1.43	36.44
15	FUTA								
		A1	0-30	70.00	20.00	10.00	SL	1.25	44.44
		A2	30-70	70.00	20.00	10.00	SL	1.27	43.56
		Btg1	70-120	50.00	40.00	10.00	SL	1.36	39.56
		Btg2	120-150	70.00	20.00	10.00	SL	1.36	39.56
16	Ijoka Olope								
		A1	0-15	50.00	30.00	20.00	SL	1.11	50.67
		A2	15-35	50.00	30.00	20.00	SL	1.11	50.67
		Btg1	35-90	60.00	20.00	20.00	SL	1.14	49.33
		Btg2	90-150	60.00	20.00	20.00	SL	1.16	48.44

BD= Bulk Density

4.8 Pedon 8 (Eleyo-owo)

The textural class was sandy clay loam and bulk density ranged between 1.12 g/cm^3 and 1.17 g/cm$^{3.}$ Porosity decreased down the profile from 50.22 (%) to 43.56 (%) at horizon Btg2.

4.9 Pedon 9 (Aladura)

The **s**urface horizons A1 and A2 were classified as sandy clay loam and Btg1was sandy loam and bulk density was 1.36 g/cm^3. Porosity ranged between 44.44 (%) horizons at the surface horizon to 39.56 (%) at the Btg2 at a depth of 70- 105 cm

4.10 Pedon 10 (Alagbado)

The clay (%) in this pedon was the highest at Bt_2 horizon 26 (%) and lowest at the surface horizon 16 (%). High sand (%) was recorded at A_2 with 69 (%). High gravel content was obtained at the Bt_2 horizon with 289 g. The Btg2 horizon has the highest bulk density of 1.36g/cm^3. Soil textures were sandy clay loam (SCL) and Sandy Loam (SL).

4.11 Pedon 11 (Adofure)

The clay (%) in this pedon was the highest at Btg2 followed by Bt_1 with 60 (%) and 50 (%) respectively and lowest was recorded at both A_1 and A_2 with 40 (%) each. High sand (%) was found at A_1 and A_2 50 (%) each). Also, high gravel content was obtained at Btg2 with 204 g. Porosity was high at Bt_1 and Btg2 with 58 (%) each. The horizons Bt_1 and Btg2 recorded the highest bulk density of 1.25 g/cm^3 each. Soil textures were sandy loam (SL) and clay loam (CL).

4.12 Pedon 12 (Olokuta Ondo Road)

In this pedon, the highest (%) clay was at A_1 (24 (%) and the lowest at Bt_1 and Btg 2 with 20 (%) each; high sand (%) at A_1, Bt_1 and Btg2 with 70 (%) each and lowest at A_2. Also, gravel content was the highest at Btg2 with 252 g content. The horizons had the highest porosity (%) of 58.11(%) at Bt_1. The highest bulk density of the horizon was recorded at Btg2 (1.16 g/cm^3). Soil texture of all horizons was Sandy Loam (SL).

4.13 Pedon 13 (Federal College of Agriculture, FECA)

All the horizons in this pedon had equal (%) of clay 20 (%). High sand (%) was found at Bt_1 and Btg2 horizons with 60 (%) each and the lowest at A_1 and A_2 with 50 (%) each. Gravel content was the highest at Btg2 with 277 g content. The A_1 horizon had the highest (%) of porosity with 56.60 (%). Bulk density was the highest at Btg2 with 1.22g/cm^3. Soil textures were Loam (L) and Sandy Loam (SL).

4.14 Pedon 14 (Seebi)

The clay (%) in this pedon is the highest at the Bt_1 horizon 50 (%) and lowest at the surface 16 (%). High sand (%) seen at the A_1 70 (%). Gravel contest was high at Bt_1 horizon with 892 g. Porosity was high at Bt_1 with 52.83(%). The highest bulk density was recorded at horizons Bt_1 and Bt_{g2} with 1.43 g/cm^3 each. Soil textures were Sandy Loam (SL), Sandy Clay (SC) and Sandy Clay Loam (SCL).

4.15 Pedon 15 (FUTA)

The highest sand (%) was obtained at A_1, A_2 and Bt_1 horizon 70 (%) each while all the horizons in the pedon had equal amount of clay (%) of 10(%) each. Gravel content was the highest at Btg2 with 204 g. Horizon Bt_1 and Btg2 had the highest bulk density of 1.36 g/cm^3 each. Soil texture was Sandy Loam (SL).

4.16 Pedon 16 (Ijoka Olope)

The highest sand (%) was obtained at the Bt_1 and Btg2 horizons 60 (%) each. Clay (%) was low in all the horizons with 20 (%) each. Gravel content was the highest at Btg2 with 277g. The horizon Btg2 had the highest bulk density of 1.16 g/cm^3. Porosity was also the highest at Btg2 horizon. Soil texture was Sandy Loam (SL).

5. DISCUSSION

5.1 Morphological Properties and Site Description of Soils in Akure North and South Local Government Areas of Ondo State

The soils were generally deep to very deep (70 to 150 cm) and had no restrictions except in pedon 3 where the depth was restricted by hard pan and this posed limitation to crops that can be grown in the study area. It has be reported that hardpans and concretions enhance lateral movement of water in soil body, impede drainage with accumulated water resulting in aeration problems and decrease sharply, the hydraulic conductivity in the direction of hardpans [10]. The justification by [11] was that soil as observed in a

profile at a particular time depended on the interaction of factors and processes of soil formation. The factors are parent materials, climate, organisms, relief time, depth, slope, etc. of the area. The absence of impenetrable layer to the depth of 150 cm from the soil surface indicated for all other pedons shows that the soil in the study area poses no limitation to root development. The occurrence of the soils of the study area on nearly flat to gently undulating landscape will encourage the cultivation of wide range of crops, as the problems of soil erosion will be minimal. The bright colour exhibited by the pedons revealed good drainage condition of the soil, except in Pedon 7 (Ogbese) where the pedon showed very high water volume. Pedon 7 (Ogbese) of the study area will support hydrophilic plants and all other pedons are good for arable and non-arable crops. However, the occurrence of mottles in the lower depth of all the pedons was an indication that there are variations in water table in the soil within and out of season. This could be attributed to the presence of impervious layer (rock) resulting in water stagnation and slow percolation [12].

The structural development of the soil was due to the stabilizing effects of organic matter in the top soil and clay minerals in the sub soil [13]. The friable consistence of the epipedon will ensure good tillage operation and easy penetration of plant roots. [14] reported that friable soil often had the optimum conditions for tillage operations, resulting in better seed bed preparation with good drainage, gaseous exchange and heat conductance.

Generally, the particle size distribution revealed that sand dominated the particle size fraction of the soil in all the profiles. This indicates that the soils of the study area will be less chemically and physically active. [15] have stated that sand has a smaller surface area (0.100-0.01 m^2g^{-1}) and it tends to be less chemically and physically active. The coarse sandy texture of the soils (characterized by high infiltration rate) will have good water penetration but the soils can be easily depleted of essential nutrients and moisture through leaching [16]. Therefore, during the dry season, when the water table is low and there is high evapo-transpiration, there will be water stress as ground supply may not be able to recharge through capillary action for the wetter zones at lower depth or from ground water table during this period [17,18] therefore opined that good management practices such as the incorporation of organic matter into the soil (especially, farm yard manure, compost and green manure) will help to bind soil particles together and thus, increase the aggregate stability of the soils. Also, subsurface horizons exhibited higher clay content as compared to the surface horizons, which might be due to illuviation process occurring during soil development as suggested by [19]. This increase in clay was an evidence of eluviation-illuviation soil from the process resulted from high and intense rainfall experienced in the study area, coupled with network of pores of coarse texture of the upper horizons that encouraged easy migration of clay suspension down the profile [20] and [21]. An outstanding feature of these soils across all profiles is moderate to high silt content 4 (%) – 30 (%). [22] opined that the increase in silt content might be due to disturbance of soil aggregate and the washing down of the finer soil aggregates down the profile.

5.2 Evaluation of the Stage of Development of Soils

The assessment of the pedons for *in-situ* weathering of the profiles showed that all the pedons had ratios of silt: clay above 0.15. This indicates that the soils have not been subjected to severe weathering and may still have some weatherable minerals [23]. This is also in alignment with [24] and [25] who reported that old parent materials usually have silt/clay ratios below 0.15 while silt/clay ratio above 0.15 indicate young parent materials. More so, the soils with silt/clay ratios less than 0.25 are at the advanced stage of weathering while those with ratios greater than 0.25 indicate a low degree of weathering. The implication of this is that, the soils of the study area are made up of young parent materials with low degree of weathering. This might be responsible for coarse texture of the soils and low nutrient status of the soil, as some of the nutrients are locked up in the parent materials.

6. CONCLUSION AND RECOMMENDA-TION

The results of the study areas have revealed that the soil of Akure North and South Local Government Area occurs on level plain with little slope gradient. The soils are generally deep and well drained at the top soil with coarse texture. The subsoils are characterized by the prominent presence of mottles which suggests that the subsoils are poorly drained also. This study also

revealed that nutrients data acquired from the laboratory could be interpolated using remote sensing integrated with GIS and this would play a vital role in understanding the nature and extent of soil nutrient distribution in the study area. The coarse texture of the soils can be managed through the use of appropriate organic manure especially, farm yard manure, compost and green manure and this will help to bind soil particles together and thus increase the aggregate stability of the soil. So also, maintenance will minimize soil crusting. Bio-organic manure will help bind the soil particles together thereby improving its water holding capacity and nutrient retention in the study area Thus, and increase usages of organic manure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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