World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:14, No:6, 2020

Soil Organic Carbon Pool Assessment and Chemical Evaluation of Soils in Akure North and South Local Government Area of Ondo State

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Abstract**—**Aggregate soil carbon distribution and stock in the soil in the form of a carbon pool is important for soil fertility and sequestration. The amount of carbon pool and other nutrients statues of the soil are to benefit plants, animal and the environment in the long run. This study was carried out at Akure North and South Local Government; the study area is one of the 18 Local Government Areas of Ondo State in the Southwest geo-political zone of Nigeria. The sites were divided into Map Grids and geo-referenced with Global Positioning System (GPS). Horizons were designated and morphological description carried out on the field. Pedons were characterized and classified according to USDA soil taxonomy. The local government area shares boundaries with; Ikere Local Government (LG) in the North, Ise Orun LG in the northwest, Ifedore LG in the northeast Akure South LG in the East, Ose LG in the South East, and Owo LG in the South. SOC-pool at Federal College of Agriculture topsoil horizon A2 is significantly higher than all horizons, 67.83 th⁻¹. The chemical properties of the pedons have shown that the soil is very strongly acidic to neutral reaction (4.68 – 6.73). The nutrients status of the soil topsoil A1 and A2 generally indicates that the soils have a low potential for retaining plant nutrients, and therefore call for adequate soil management.

Keyword**—**Soil organic carbon, horizon, pedon, Akure

I. Introduction

Carbon in soils is mainly of two forms; inorganic and organic and this is present in the Earth's crust as fossil fuels and sedimentary rocks such as limestone, dolomite, and chalk. Mineralization of fresh plant residue can increase the mobility of labile carbon hence carbon pool meanwhile, anthropogenic activities affect soil quickly due to severe disturbance leading to loss of SOC [1]. The soil in Akure metropolis has been greatly disturbed due to human and agricultural practices for more than ten decades, human activities manipulate vegetation- and soil-related processes such as land-use change and agricultural management. These eventually alter C-cycling patterns of the ecosystem. The rate of nutrients root uptake cum soils carbon loss due to loss of CO_2 is in the range of 50 to 70% [2] and this had tremendous effects on the SOC pool and chemical properties. It has been reported that trees and forest soils store more carbon than grasslands and grass vegetation [3] [4]. Some other deliberations have evolved in recent times on differences in the effectiveness of trees and native grasses in serving as carbon sinks [5] but less systematic study has been undertaken to estimate the SOC pool in Akure and being a major agricultural state in Nigeria hence the need to evaluate carbon storage in the soil and related nutrients.

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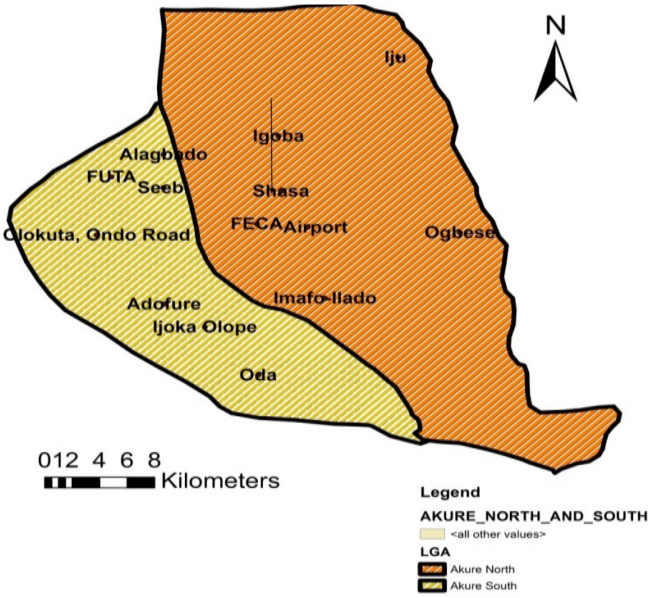

Fig. 1 Map of Akure North and South LG Area showing the study sites

A. Research Methodology

The study was carried out in Akure North and South Local Government Area (LGA) of Ondo State Area of Ondo State, South West Nigeria. The sites were divided into Map Grids and pedon was established within the grids. Seven pedon were established in Akure North. Seven were also dug in Akure South LG Area of Ondo State South West, Nigeria. 500 g soil representative sample were collected from each of the designated horizon. They were packed into 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. Soil types were identified with respect to survey manual [3]. Munsell colour chart was used to describe the soil. Replicated samples were taken from pedogenic horizons and analyzed in the laboratory for determination of SOC-pool taken at 0–30 cm.

SOC-pool was calculated as: SOC stock = d * BD * (Ctol – Cmin) * CFst where: SOC = soil organic carbon [kg m^{-2}] Ctot and Cmin = total and mineral (or inorganic) carbon content [g g^{-1}] d = depth of horizon/depth class [m] BD = bulk density [kg m^{-3}] CFst = correction factor for stoniness, including subtraction of gravel and stones. [4] Replicated SOC pool for each horizon was also calculated, data were subjected to analysis of variance (ANOVA), and the differences in the means were separated with New Duncan Multiple Range Test (NDMRT) at $P < 0.05$ while soil nutrient analysis was calculated using simple mean.

B. Climate of Study Area

Akure north and south LG Area falls within the rain forest region of Southwestern Nigeria. It has a typical humid climate characterized by alternating wet and dry seasons. This can be sub-divided into the long wet season from April to July and the short dry season in the month of August. The short wet season ranges from September to late October and the long dry season from early November to March. The local harmattan commences between December and February. The area has a bimodal or two peak rainfall regimes with peaks between June-July and September-October.

C. Laboratory Analysis

Soil samples collected were analysed using standard procedures. All the soil samples were air-dried and then sieved using a 2-mm sieve. Particle sizes larger than 2 mm were weighed as gravel content and expressed as percentage

$$\{\frac{weight\ of\ gravel}{Total\ \mathbf{weight}\ of\ the\ soil\ sample} \text{ X } 100\ \%\}.$$

A subsample was taken from each sample, finely ground and sieved using a 0.5-mm sieve for organic carbon and total nitrogen determination. Particle size distribution of the soil was determined [5]. The degree of weathering of the parent materials of soils of the area was determined by calculating the ratio of silt content to that of clay [6]. Soil pH was determined using a glass electrode in 1:2 soil: water ratio [18]. Exchangeable bases were extracted with neutral NH_4OAc solution; calcium (Ca^{++}) and magnesium (Mg^{++}) were determined by the atomic absorption spectrophotometer (AAS) and potassium (K^+) and sodium (Na^+) were determined by flame emission photometry [7]. The Walkley – Black oxidation method [8] was used to determine organic carbon (OC). Available phosphorus was determined by method of [9]. Total nitrogen was determined by the micro-Kjeldahl digestion and distillation method as described by [10]. Soil electrical conductivity was measure by conductivity meter [11]

II. Results and Discussion

A. Akure North Carbon Pool

Table I shows the SOC-pool in Akure north LGA Profiles. Soil pedon in Igoba, A1 (0-30 cm) SOC-pool was 59.24a th^{-1}, Saasa Btg1 (30-90 cm) was 58.21ab, th^{-1}, Btg2 was (90-120 cm) 54.67b th^{-1}. The SOC-pool generally decreases down the pedons except for pedon at Oda, A2 (30-70 cm) was significantly higher (40.50a th^{-1}) similar observation was noticed in Imafo-Ilado A2 (25-70 cm) (30.04a. th^{-1}). Saasa pedon A1 (0-30 cm) was 58.68a th^{-1}. Btg1 (30-90 cm) was 53.88b th^{-1} while Btg2 (90-150 cm) was 50.17b th^{-1}.Two horizons were observed in Airport area with high bulk density of 1.52 gcm^{-3} in Btg1 (30-70 cm) horizon, the C-pool was 3.95b th^{-1}. SOC-POOL-pool in Iju, Igoba, Eleyowo, Ogese and Aladura pedons shows that the OC is significantly high at A1 and decreases down the horizons.

TABLE I
Akure North Carbon Pool

Horizon	Depth	OC (%)	OM (%)	BD gcm^{-3}	SOC-POOL ($t\ ha^{-1}$)
		Igoba			
A1	0-30	3.07a	5.29a	1.12b	59.24a
Btg1	30-90	2.56b	4.41b	1.32a	58.21ab
Btg2	90-120	2.37b	4.08b	1.34a	54.67b
		Saasa			
A1	0-30	3.04a	5.24a	1.12c	58.68a
Btg1	30-90	2.44b	4.21b	1.28b	53.88b
Btg2	90-150	2.22b	3.83c	1.31a	50.17b
		Airport			
A1	0-30	0.95a	1.64a	1.25a	20.50a
Btg1	30-70	0.15b	0.26b	1.52b	3.95b
		Oda			
A_1	0-30	1.71b	2.95b	1.25b	36.87b
A_2	30-70	1.88a	3.24a	1.25b	40.50a
Btg1	70-100	1.15c	1.98c	1.31a	25.93c
Btg2	100-150	1.02c	1.76c	1.35a	23.76c
		Imafo-Ilado			
A_1	0-25	1.53a	2.64a	1.12ab	29.56a
A_2	25-70	1.50a	2.59a	1.16ab	30.04a
Btg1	70-100	1.12b	1.93b	1.25a	24.12b
Btg2	100-150	1.12b	1.93b	1.25a	24.12b
		Iju			
A1	0-23	1.36a	2.34a	1.18b	27.61a
A2	23-40	1.05b	1.81b	1.23a	22.26ab
Btg1	40-75	1.20ab	2.07ab	1.35a	27.94a
Btg2	75-120	0.11b	0.19c	1.39a	26.41b
		Ogbese			
A1	0-26	2.12a	3.69a	1.14ab	42.06a
A2	26-47	1.85b	3.22b	1.12ab	36.06b
Bt1	47-90	1.59b	2.77c	1.13ab	31.30bc
Btg2	90-120	1.33ab	2.32c	1.25a	29.00c

Means along the column with the same superscript are not significantly different by DMRT ($p < 0.05$)

B. Chemical Properties of Soil in Akure North

Table II revealed the chemical properties of the soils in Akure north LGA [12]. Most plant nutrients are readily available at very slightly acid to very slightly alkaline soil reaction (pH range of 6.2-7.3). But pedon 7 (Ogbese) shows strongly acidic nature (5.5). This could be due to water logged nature of the soil; soil pH is more acidic where water resides [13]. Liming is necessary in the area to ameliorate the effect of the acid. The decreased value of OC with depth in all the pedons is probably due to the concentration of more organic matter at the top soil [14]. Cultural method of farming is recommended, plant residue incorporation into the soil will also improve the level of soil organic matter [15]. The low content of available phosphorus in the soils may be due to fixation of phosphorus on iron (Fe) in the soils [16] and biological fixation of phosphorus in microbial bodies can lead to slow release of phosphorus by the soil. Lowest EC is observed in Pedon 2 (Saasa).

TABLE II
CHEMICAL PROPERTIES OF SOIL IN AKURE NORTH

Horizon	Depth (cm)	pH (H20)	Total N (%)	Avail. P (mg/kg)	K+ (cmol/kg)	Na++ (cmol/kg)	Mg++ (cmol/kg)	Ca++ (cmol/kg)	EC (µS)
					Igoba				
A1	0-23	6.60	1.11	1.16	0.29	0.27	0.88	1.75	24.28
A2	0-47	6.22	1.03	1.08	0.22	0.23	0.18	1.23	24.29
Bt1	47-90	5.86	1.05	1.06	0.25	0.14	0.48	1.71	23.40
Btg2	90-120	6.01	1.07	1.06	0.28	0.22	0.78	1.29	23.51
					Saasa				
A1	0-30	5.33	1.52	22.10	0.92	1.00	0.54	2.85	0.50
Bt1	30-90	5.56	1.22	24.00	0.57	1.13	0.50	3.70	0.53
Bt2	90-150	6.48	1.11	29.25	0.60	0.67	0.55	3.70	0.40
					Airport				
A1	0-30	6.17	0.48	0.80	0.51	0.36	2.40	2.10	16.01
Bt1	30-70	6.13	0.08	0.16	0.32	0.60	1.20	1.00	15.99
					Oda				
A1	0-30	6.60	0.86	1.22	0.32	0.15	2.67	1.03	15.46
A2	30-70	6.69	0.94	1.22	0.29	0.16	1.13	1.17	14.38
Bt1	70-100	6.75	0.58	1.22	0.25	0.16	1.24	1.15	15.49
Btg2	100-150	6.73	0.51	1.12	0.41	0.16	1.75	1.11	15.48
					Imafo- Ilado				
A1	0-25	6.71	0.77	0.04	0.18	0.13	1.13	0.87	4.40
A2	25-70	6.63	0.75	0.02	0.16	0.16	1.20	1.06	5.46
Bt1	70-100	6.74	0.56	0.19	0.19	0.14	1.61	0.89	4.42
Btg2	100-150	6.77	0.56	0.27	0.17	0.12	0.82	0.86	5.48
					Iju				
A1	0-23	6.50	0.62	1.67	0.46	0.33	0.41	1.11	11.94
A2	23-40	6.79	0.50	1.27	0.54	0.27	0.31	1.00	11.56
Btg1	40-75	6.09	0.41	1.47	0.63	0.30	0.31	0.89	11.19
Btg2	75-120	6.04	0.42	1.08	0.72	0.28	0.40	0.78	11.81
					Ogbese				
A1	0-20	5.55	1.79	3.04	0.66	0.47	0.83	1.62	16.48
Bt1	20-60	5.65	2.25	1.96	0.52	0.47	0.45	1.74	17.90
Btg2	60-100	5.71	2.47	1.21	0.45	0.48	0.72	1.35	21.61

Means along the column with the same superscript are not significantly different by DMRT ($p < 0.05$)

C. Akure South Carbon Pool

Table III revealed the soil carbon pools of Akure South. SOC-pool was highly dispersed with depth in all the pedon evaluated in Akure South LG area of Ondo State. Greater SOC-pool is observed at the top soil of horizon A1 and A2. Alagbado profile shows significant difference among the horizons Btg2 at 90-150 cm shows the least SOC-pool in the profile. The average SOC-pool for pedon in Adofure horizons was significantly higher than other pedon in Akure South. There was no significant difference of SOC-pool in A1 (0-20 cm) (53.42ab th-^{1}), A2 (20-30 cm), 55.79ab th^{-1}, Btg2 (90-150 cm) 58.37ab th^{-1}. Olokuta soil pedon SOC-pool at A1 (0-20 cm) was significantly different from A2.The subsoil Btg1and Btg2 were not significantly different in OC-pool from one another. There was significant difference in in Federal college of agriculture (FECA) A1, at depth 0-20 cm; OC pool was 57.83ab th^{-1} at depth 90-150 cm, the trend was different in Seebi showing poor organic pool in A2 at depth 30-70 cm the OC pool was 1.20d th^{-1}. The same trend was observed in Ijoka-Olope horizon Btg2 (10.40c Th-1). FUTA soil profile was higher in SOC-pool and these was observed in Btg2 (70-120 cm), 39.84a th^{-1}. The same trends were observed in FECA with higher percentage of SOC in surface and subsurface horizons. The higher percentage observed in FECA may be due to active mineralization at top soil A1 and A2. These observations may be due to organic inputs from well conserved environment which encourage rapid decomposition and nutrients mineralization active and close to the soil surface.

Akure south results show greater difference from one profile to other this may be due to soil management, SOC-pools are greater on A1 and A2 this may be due to organic inputs which are rapidly decomposed and nutrients mineralization active close to the soil surface.

D. Akure South LGA Soil Chemical Properties Pedon 8-14

The results of the chemical properties of the soils are presented in Table IV. The surface (0-30 cm) soil reaction ranged between strongly acidic and neutral (5.25-6.60) while the sub-surface horizons ranged from moderately acid to neutral in reaction (5.65-6.76). OC content ranged from moderately high to high (1.12% to 2.65%) in the surface soil horizons. The value however decreased irregularly with increasing depth in all the pedons. Relatively low amounts of available phosphorus (< 5 mg/kg) were observed in all the pedons. For the exchangeable bases; K had high amount in all the pedons, while Ca and Mg were low in all the pedons. Increasing soil acidity decreases exchangeable bases ability of the soil to retain K, and this may cause K to be more prone to leaching. An integrated nutrient management system, with good ecological management is suggested for the study area. Soil electrical conductivity (EC) is the amount of salts in soil which affect its health. High salt concentration in the soil hinders plant growth by affecting the soil-water balance. Conductivity of soils generally varies depending on the volume of moisture held by soil particles. Sandy soils have a low conductivity, soil high in silts conduct moderately while clay soils have a high conductivity rate. Soil particle size and distributions correlate directly to soil EC. [17]. The EC of the study area shoes moderate salt level. Pedon 14 Ijoka- Olope has the lowest level of EC for the study area.

III. Conclusions and Recommendation

SOC-pool study for the two LGA was found maximum in *Saasa* A1, 0-30 cm (58.68a t ha^{-1}) in Akure north followed by *FECA* (57.83ab t ha^{-1}) in the south LGA. This result may be due to high level of animal and plant waste deposit in Saasa. FECA soil is well conserved and protected from anthropogenic activity. More carbon pool is observed in the southern part of the state than in the North based on the study sites hence better agricultural performance is expected. Airport study area has the lowest pool of SOC 20.50 t ha^{-1} at A1 and 3.95b t ha^{-1}.

The low carbon and fertility status of the Northern LG Area can be managed through the use of appropriate organic manure and chemical fertilizers. Bush burning should be avoided to boost the OC of the soil for maximum soil productivity. Cover crops should be encouraged for nitrogen fixation and to prevent erosion.

TABLE III
AKURE SOUTH CARBON POOL

Horizon	Depth	OC (%)	OM (%)	BD gcm^{-3}	C-POOL (t ha^{-1})
		Alagbado			
A1	0-15	1.72a	2.96a	1.23a	36.40a
A2	15-30	1.16ab	2.00a	1.29a	25.80b
Btg1	30-90	1.18ab	2.03a	1.32b	26.79b
Btg2	90-150	0.95b	1.64b	1.36b	22.30c
		Adofure			
A1	0-20	2.77a	4.77a	1.12ab	53.42ab
A2	20-30	2.79a	4.81a	1.16ab	55.79ab
Btg1	30-90	2.84a	4.90a	1.25a	61.25a
Btg2	90-150	2.71a	4.67a	1.25a	58.37ab
		Olokuta, Ondo Road			
A1	0-20	2.70a	4.65a	1.11a	51.61a
A2	20-30	1.33b	2.29ab	1.11a	25.41b
Btg1	30-90	1.10b	1.90b	1.14a	21.66b
Btg2	90-150	1.12b	1.93b	1.16a	22.38b
		FECA			
A1	0-20	3.02ab	5.21a	1.11a	57.83ab
A2	20-50	3.45a	5.95a	1.14a	67.83a
Btg1	50-90	2.53b	4.36b	1.15a	50.14c
Btg2	90-150	2.05bc	3.53b	1.22a	43.06d
		Seebi			
A1	0-30	1.53a	2.64ab	1.27b	33.52b
A2	30-70	0.05c	0.09c	1.34a	1.21d
Btg1	70-100	0.95b	1.64b	1.43a	23.45c
Btg2	100-150	2.07a	3.57a	1.43a	51.05a
		FUTA			
A_1	0-30	1.56ab	2.69b	1.25a	33.62a
A_2	30-70	1.37b	2.36c	1.27a	29.97b
Btg_1	70-120	1.70a	2.93a	1.36a	39.84a
Btg_2	120-150	1.33b	2.29c	1.36a	31.14c
		Ijoka - Olope			
A_1	0-15	3.02a	3.48a	1.11a	38.62a
A2	15-35	1.45b	2.50b	1.11a	27.75ab
Btg_1	35-90	1.53b	2.64b	1.14a	30.09b
Btg_2	90-150	0.05c	0.09c	1.16a	10.44c

Means along the column with the same superscript are not significantly different by DMRT ($p < 0.05$)

TABLE IV
AKURE SOUTH LGA SOIL CHEMICAL PROPERTIES PEDON 8-14

Horizon	Depth (cm)	pH (H20)	Total N (%)	Avail. P (mg/kg)	K+ (cmol/kg)	Na++ (cmol/kg)	Mg++ (cmol/kg)	Ca++ (cmol/kg)	EC (µS)
A1	0-15	4.70	0.86	0.74	0.98	0.41	1.10	4.05	15.96
A2	15-30	5.07	0.93	0.12	0.53	0.38	1.50	3.05	16.63
Bt1	30-90	5.29	0.99	0.10	0.47	0.19	1.00	2.10	12.90
Btg2	90-150	5..02	0.48	0.07	0.39	0.31	1.90	2.30	15.96
A1	0-20	5.75	1.39	0.11	0.89	0.51	2.70	1.15	15.97
A2	20-30	5.08	1.40	0.15	0.50	0.39	2.20	1.05	16.04
Bt1	30-90	5.78	1.42	0.11	1.23	0.76	2.70	1.75	15.92
Btg2	90-150	5.02	1.36	0.07	0.92	0.67	2.50	1.15	12.88
A1	0-20	5.05	1.35	0.05	1.20	0.46	2.20	1.25	16.02
A2	20-30	5.14	0.67	0.05	0.30	0.33	2.50	1.25	12.92
Bt1	30-90	4.81	0.55	0.04	0.74	0.56	2.70	1.65	12.92
Btg2	90-150	4.76	0.56	0.05	0.63	0.49	2.50	1.85	15.90
A1	0-20	5.00	1.51	0.11	1.54	0.39	3.30	2.55	12.87

Horizon	Depth (cm)	pH (H20)	Total N (%)	Avail. P (mg/kg)	K+ (cmol/kg)	Na++ (cmol/kg)	Mg++ (cmol/kg)	Ca++ (cmol/kg)	EC (μS)
A2	20-50	4.76	1.73	0.07	1.48	0.47	3.50	2.10	15.96
Bt1	50-90	5.09	1.27	0.57	1.56	0.41	4.70	2.60	12.91
Btg2	90-150	5.17	1.03	0.80	0.51	0.36	2.40	2.50	16.01
A_1	0-30	5.09	0.31	0.57	0.56	0.41	2.70	1.60	12.91
Bt_1	30-70	5.17	0.01	0.80	0.51	0.36	2.40	1.50	16.01
Bt_2	70-100	5.13	0.19	0.06	0.62	0.40	2.20	1.80	15.99
Btg_3	100-150	4.68	0.41	0.06	0.24	0.45	2.80	1.00	15.97
A_1	0-30	4.95	0.78	0.06	1.24	0.46	2.30	1.25	12.81
A_2	30-70	5.11	0.69	0.06	1.14	0.46	2.70	1.25	16.06
Bt_1	70-120	5.05	0.85	0.05	1.20	0.46	1.20	1.25	16.02
Btg_2	120-150	5.14	0.67	0.05	0.30	0.33	1.50	1.25	12.92
A_1	0-15	5.00	0.11	0.54	0.39	2.30	1.55	12.87	5.00
Bt_1	15-35	5.76	0.07	0.48	0.47	2.50	1.10	15.96	5.76
Btg_2	35-90	5.09	0.57	0.56	0.41	2.70	1.60	12.91	5.09
Btg_2	90-150	5.17	0.80	0.51	0.36	2.40	1.50	16.01	5.17

Means along the column with the same superscript are not significantly different by DMRT ($p < 0.05$)

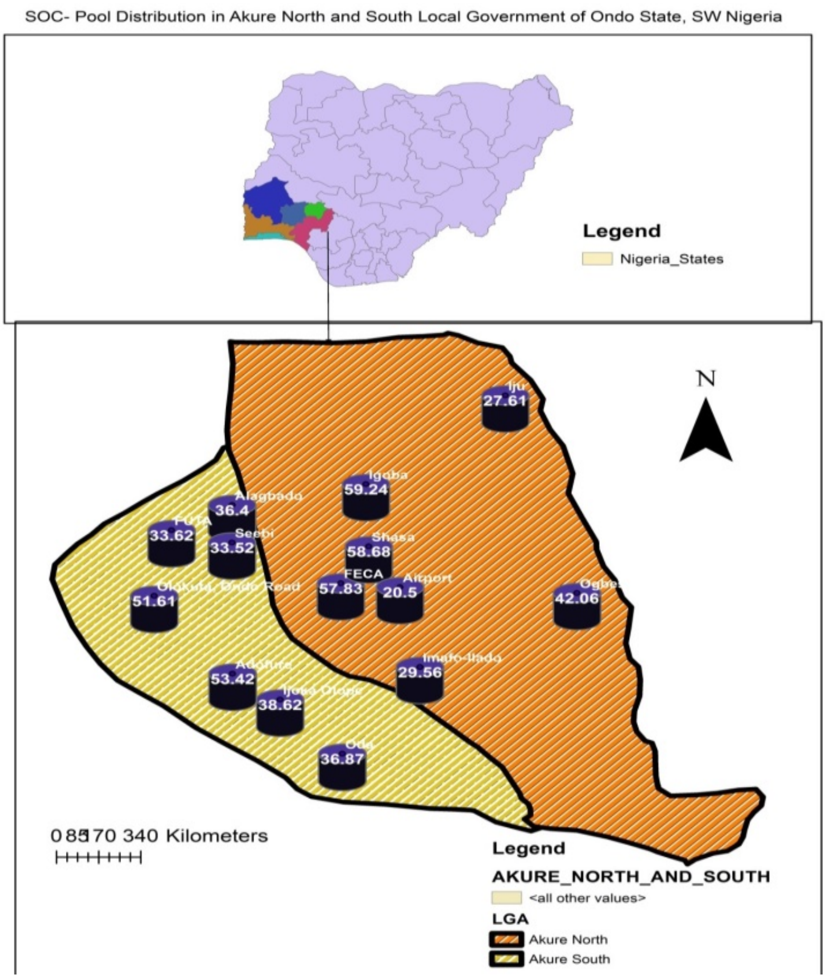

Fig. 2 SOC-Pool distribution in Akure North and South LGA of Ondo State SW, Nigeria

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