

*Full Length Research Paper*

# **Characterization and agricultural potentials of some pedons derived from sand stone parent rock near Abeokuta, Southwestern Nigeria**

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**Successful crop production requires the knowledge of soil variation and the evaluation of the agricultural potentials of the land. Detailed land resource survey of approximately 100 ha land in Abeokuta North Local Government Area of Ogun State was carried out. Identified soil mapping units were examined in modal profiles. The soils were classified using the USDA Soil Taxonomy, FAO/IUSS World Reference Base (WRB) system and local soil series methods. Five soil mapping units were identified and were classified as Ilaro Series (Kanhaplic Haplustalf), Ibeshe (Typic Kandiuustalf), Kulfo (Udic Kandiuustalf), Molo (Rhodic Kandiuustalf) and Otteyi Series (Lithic Haplustept). The soils were classified as Alfisols (71.56%) and Inceptisols (28.44%). Land Capability Classification (LCC) revealed that Ilaro, Ibeshe and Molo series belong to Capability Class II while Kulfo series was Class III but Otteyi series is of non-arable Class VI. Otteyyi Series had severe limitations of very shallow soil depth, high slope gradient and high gravel content. The area has good potential for crop production if soil fertility can be managed with appropriate fertilizer application and seasonal water deficit ameliorated by supplemental irrigation. Otteyi Series that is non-arable could be used for farm buildings and other physical infrastructures or animal grazing.**

**Key words:** Land evaluation, fertility capability class, soil series, limitations, arable cropping.

## **INTRODUCTION**

Soils differ in their behavior due to differences in morphological, physical, chemical, biological and mineralogical properties (Msanya, 2018). These variations are due to differences in soil forming processes operating on different parent materials, under different climatic, topographic, and biological conditions over varying periods of time (Soil Survey Staff, 1993). In the past, decisions on land use are made indiscriminately based

mainly on economic, cultural and political considerations, with little or no consideration for the biophysical status of the soils (Orimoloye et al., 2007; Nuga and Akinbola, 2011). The knowledge of the pattern of soil distribution and the characteristics of each unit of soil are very essential for a better understanding, use and management of soils (Ogunkunle, 2005; Lufega and Msanya, 2017). This will help maximize sustainable production

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**Plate 1.** Google earth imagery of the study area near Abeokuta.

and satisfy the diverse needs of society while at the same time conserving fragile ecosystems. A soil survey delineates the soil types in a given area, classifies soils according to a standard system of classification, plots boundaries of the soils on a map and makes predictions about the behaviour of the soils (Soil Survey Staff, 1993). The information is interpreted in land evaluation to assist the development of land use plans, evaluates and predicts the effects of land use on the environment (Shepande, 2002). The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use patterns (Hubrechts et al., 2004).

Fasina et al. (2007) had observed an increasing demand for information on soils as a means to enhancing agricultural production in Nigeria. Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of experience and technology from one place to another and helps to compare soil properties. It is therefore pertinent that for the full potentials of an agricultural land to be maximized, there is need to have a good understanding of the different alternative uses that a land can be put as land use ought not to be based primarily on the needs and demands of users, but rather on the understanding of the suitability of each land for the intended use in order to achieve environmental sustainability (Nuga and Akinbola, 2015). There is therefore an urgent need for evaluation of

agricultural lands and associated planning, owing to problems faced in recent years in the form of increasing pressure on agricultural lands from other uses, coupled with increasing demand for agricultural products due to population growth.

Soils of the Abeokuta North Local Government Area of Ogun State, Nigeria, are mainly of the sedimentary origin. Oral tradition from the locals indicates that the soils of the study area have been variously used at different times by peasants and institutions without any systematic soil study, leading to decline in yield and subsequent abandonment. A renewed interest in agricultural development by government and private investors has led to the allocation of large portions of this track of land to interested commercial farmers. A platform is thus created for a systematic soil study in this area to prevent seeds being sown on the proverbial 'stony ground'. This study was carried out therefore to characterize the soils of the study area and assess the land for general arable cropping.

## MATERIALS AND METHODS

### Description of the study site

The study area by its geomorphic and landscape characteristics typifies a wide expanse of land covering over 200,000 ha of land spread across several local government areas including Egbado/Yewa North, Owode and Ewekoro LGAs. The detailed study was carried out on a rectangular shaped land area situated along JogaOrile and llewo-Orile earth road, west of Abeokuta town. It is defined between latitudes 7° 8'5.60"N and 7° 8'38.40"N and longitudes 3° 8'44.40"E and 3° 9'45.30"E. Plate 1 shows the satellite imagery of the study area and Figure 1 the location map of

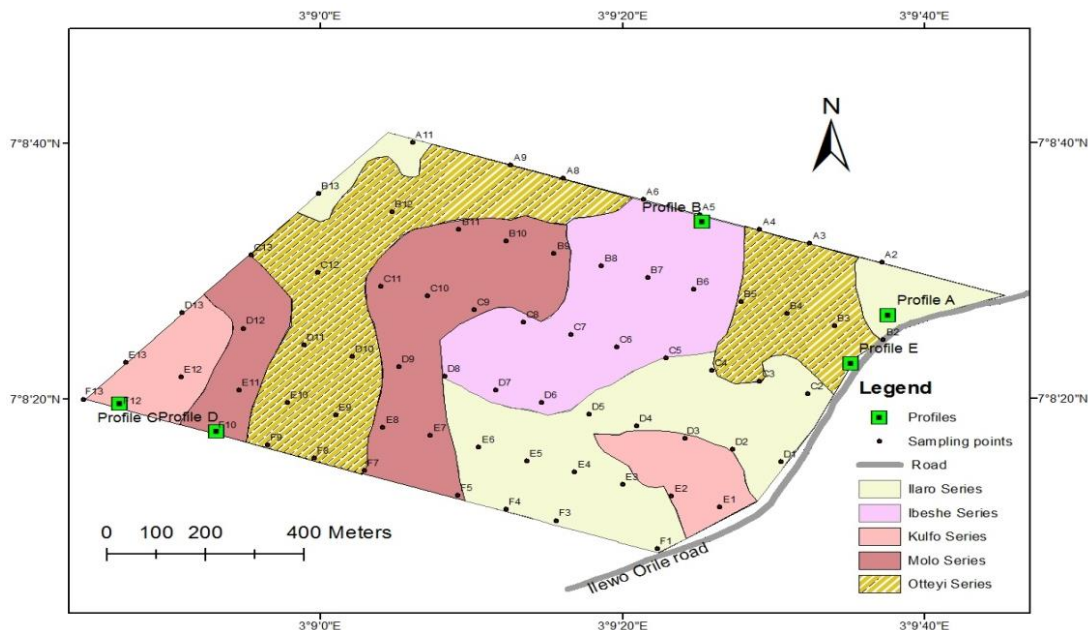


Figure 1. Soil map of study area near Abeokuta.

Table 1. Mean monthly weather condition at Abeokuta (20 km west of the study area).

Weather element	Months												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rainfall (mm)	4.4	0.0	137.1	102.7	84.2	252.8	150.6	182.1	245.6	194.9	5.4	0	1368.8
Rainy days	1	0.0	4	8	5	18	10	22	18	12	2	0	83
Evapotranspiration (ml)	5.2	9.1	6.6	3.3	3.1	2.1	1.7	1.5	1.8	1.8	3.4	5.1	3.7
Min. Temp. (°C)	19.9	17.3	20.6	22.2	21.8	21.1	20.7	20.7	21.3	21.8	22.5	19.1	20.7
Max. Temp. (°C)	34.0	35.1	36.0	32.3	32.2	29.9	28.1	27.8	29.5	29.4	33.4	33.8	31.8
Wind speed (km/h)	76.9	70.3	98.2	12.6	114.4	96.4	68.6	50.9	13.8	23.7	10.4	10.5	53.9
Soil (30 cm) Temp (°C)	37.9	37.9	39.6	38.2	37.9	35.7	34.1	33.3	31.5	34.9	38.3	37.4	36.4
RH at 0900 h (%)	79	46	68	81	82	84	87	89	86	86	77	65	77

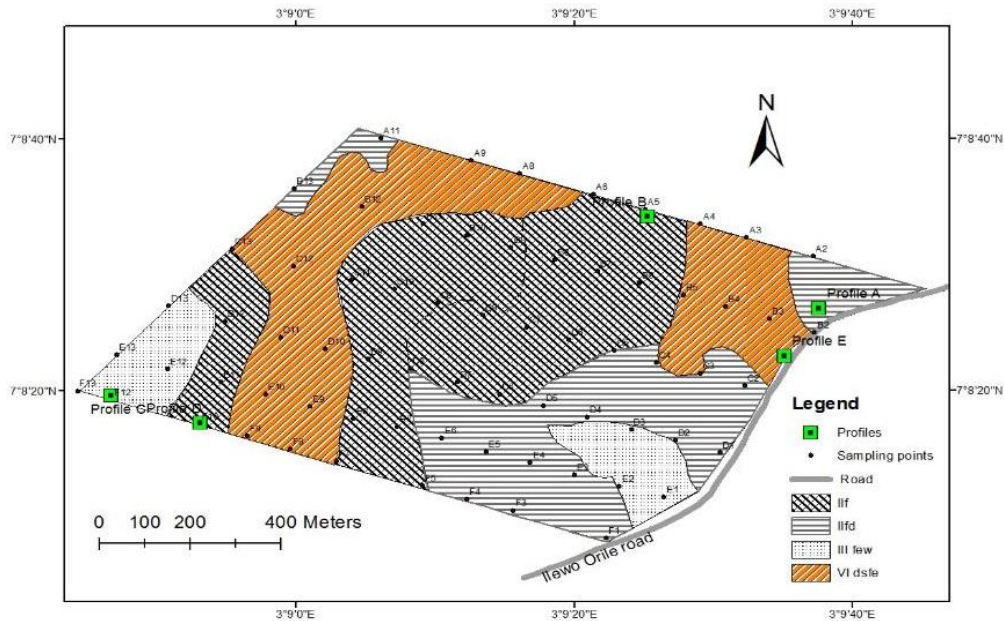
Source: Department of Meteorological Services, Abeokuta (2003-2012).

the study area. The study area is located within the Zone Q (Very humid Lagos-Benin-Asaba lowlands) of the Agro-ecological zones of Nigeria (Ojanuga, 2006). The mean annual rainfall of the area is about 1,368 mm (Abeokuta). Length of dry season ranges between 120 and 130 days. The mean daily maximum and minimum temperature of 32 and 21°C, respectively were recorded at Abeokuta (Table 1). The study area belongs to the sedimentary upland underlain by Tertiary and Cretaceous sedimentary rocks (mainly sands and clays, sandstone and shales) (Olabode and Mohammed, 2016). The land area is characterized by ironstone capped sandstones overlaying heavily mottled ferruginized clay. The dominant land use type in the area is mainly cassava-based arable cropping.

#### Field studies

A rigid grid method of soil survey was adopted for the land resource

survey in May, 2015. The extent of the area to be surveyed was determined with the help of a perimeter survey. Transects were laid out at 200 m apart and auger observations were taken at 100 m interval along the transects to ensure at least one observation in every 2 ha of land. Examination points were pre-determined in a GIS environment and the co-ordinates were pre-loaded into a Global Positioning System (GPS) device with which the points were located on the field. With the aid of Dutch Soil Auger and Munsell Soil Colour Charts, the soils morphological properties were examined at soil depth intervals of 0 - 15, 15 - 30, 30 - 60 and 60 - 90 cm except where plinthite or hard pan did not permit augering to the depth of 90 cm. Thereafter, using the soil morphological and physical properties, similar examination points were grouped together at the series level to form mapping units. Five mapping units were identified. In each of the mapping units, modal profile pits were dug, described and sampled according to international standards of soil profile description (FAO, 1991). In addition, surface soil (0-30 cm depth) samples were collected at each auger



**Figure 2.** Land capability classification map of the study area.

examination point for soil fertility assessment. The soil samples were appropriately labeled and conveyed to the laboratory for processing and analysis for the physical and chemical properties of the soils. All necessary environmental information relating to the study area and the soil morphology were recorded on a proforma. A total of 84 soil samples made up of 26 profile and 58 surface soil samples were taken from the study area for analysis.

### Laboratory analysis

The soil samples were air dried, crushed and sieved through a 2mm mesh. The gravel content (portion with particle size greater than 2 mm in diameter), was calculated as a percentage of the total air-dried soil. The particle size fractions were determined by the modified hydrometer method. The soil pH was determined in 1:1 soil: water ratio and potassium chloride (KCl) media using glass electrode pH meter. Organic carbon was estimated by Dichromate wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by the micro-Kjeldahl method (Jackson, 1958). Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945), while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral Ammonium acetate (NH<sub>4</sub>OAC). Calcium, Potassium and Sodium were measured through flame photometer, while Magnesium was determined by Atomic Absorption Spectrophotometer (Rhoades, 1982). Exchangeable acidity was determined by 1N KCl extraction and titrated with 0.05N NaOH solution (Black, 1975). Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micro-nutrients (Fe, Mn, Cu and Zn) were determined in normal hydrochloric acid (1N HCl) and evaluated using the Atomic Absorption Spectrophotometer (AAS) (Jackson, 1958). Base saturation was computed as the summation of the basic cations (Edmeades, 1982).

### Soil classification

The soil types on the study site were identified, characterized and

classified using two international systems (Keys to Soil Taxonomy by Soil Survey Staff, 2014; WRB System of FAO, 2014). The soils were also classified at the series level using the approach of Moss (1957) that described the soils of sedimentary deposits of Southern Nigeria. The modified Land Capability Classification (LCC) system of the USDA by Klingebiel and Montgomery (1961) was adopted for the evaluation of the study site for sustainable land management for arable crop production and general land use. Fertility Capability Classification (FCC) was carried out based on the results of laboratory analyses of the top soil samples, along with their morphological properties as outlined by Sanchez et al. (2003).

## RESULTS

Five soil mapping units were delineated within the study area. The soils are generally sandy loam at the top with the clay content generally increasing with depth. The soil map of the study area is presented in Figure 2. The physical/morphological and chemical properties are presented in Tables 2 and 3, respectively while the pedological classifications of the soil are shown in Table 4.

### Soil physical and morphological characteristics

The soils Mapping Unit A was classified as Ilaro Series. The soils are well drained, friable to firm consistence with sub-angular blocky structure at depths from 17 cm. They are very dark brown (7.5YR 3/3 moist) at the top and become dark red (2.5YR 4/6 moist) at the subsoil. These are underlain by variegated yellow (10YR 8/6 moist) and strong brown (7.5YR 4/6 moist) mottled sandy clay loam plinthic layer that is not indurated but soft.

**Table 2.** Physical and morphological properties of the soils of the study area.

Profile	Hor	Depth cm	Gravel	Sand (%)	silt	Clay	Texture	Colour	Mottles	Structure	Consistency	Roots	Stoniness	Boundary
A	A	0-17	1.21	80.0	9.4	10.6	SL	7.5YR 3/3	-	fc	fc	mx, ma	Nil	sm, cl
	AB	17-36	7.2	76.0	7.4	18.6	SL	5YR4/6	-	sab	fr	md, ma	Nil	sm, cl
	Bt1	36-61	2.6	54.0	5.4	40.6	SC	2.5YR4/6	-	sab	hd	mx, fi	Nil	sm, cl
	Bt2	61-92	2.2	54.0	3.4	42.6	SC	2.5YR 4/6	-	sab	hd	md, vfw	Nil	sm, cl
	Btcv	92-146	16.7	68.0	11.4	20.6	SCL	7.5YR4/6	10YR 8/6	m	hd	Nil	Nil	-
B	A1	0-14	2.86	80.0	9.4	10.6	SL	10YR 5/2	Nil	md,cr	fr	mx, ma	Nil	sm, cl
	A2	14-29	1.72	78.0	5.4	16.6	SL	7.5YR 5/3	Nil	sab	fr	co, fw	Nil	sm, cl
	Bt1	29-58	4.10	64.0	3.4	32.6	SCL	7.5YR 3/6	Nil	sab	mod, hd	fi, vfw	Nil	sm, df
	Bt2	58-89	1.41	58.0	7.4	34.6	SCL	5YR 6/6	Nil	sab	hd	md, vfw	Nil	sm, df
	Bt3	89-120	0.66	60.0	5.4	34.6	SCL	5YR 7/8	Nil	sab	hd	fi, vfw	Nil	sm, df
	Bt4	120-158	5.09	64.0	7.4	28.6	SCL	5YR 6/8	Nil	sab	Hd	Nil	Nil	-
C	A1	0-17	0.70	80.0	9.4	10.6	SL	7.5YR 3/2	Nil	fc	Fr	mx, ma	Nil	sm, cl
	A2	17-36	0.56	84.0	7.4	8.6	LS	7.5YR 4/3	Nil	sab	Fr	mx, ma	Nil	sm, cl
	B1	36-70	0.75	76.0	7.4	16.0	SL	5YR4/4	Nil	sab	Fr	mx, ma	Nil	sm, df
	B2	70-92	0.93	74.6	7.4	18.0	SL	5YR 4/6	Nil	sab	Fr	mx, ma	Nil	sm, df
	Bt1	92-136	1.83	70.6	11.4	20.0	SCL	5YR 4/6	Nil	sab	Fm	fi, fw	Nil	sm, cl
	Btv	136-160	2.57	48.6	9.4	42.0	SC	5YR 5/6	7.5 6/8YR	sab	Fm	fi, fw	Nil	-
D	A	0-15	2.75	70.6	9.4	20.0	SCL	10YR 4/2	-	md, cr	Fr	mx, ma	Nil	sm, cl
	AB	15-27	2.9	68.6	17.4	14.0	SL	7.5YR 5/4	-	sab	Fr	co, ma	Nil	sm, cl
	Bt1	27-56	3.5	58.6	9.4	32.0	SCL	2.5YR 4/6	-	sab	Hd	mx, fw	Nil	sm, cl
	Bt2	56-117	1.7	48.6	9.4	42.0	SC	2.5YR 4/8	-	sab	Hd	md, vfw	Nil	sm, df
	Bt3	117-140	4.7	62.6	9.4	28.0	SCL	2.5YR 5/8	2.5Y 7/6	sab	Hd	md, vfw	Nil	-
E	AC	0-10	31.5	74.6	3.4	22.0	SCL	10YR 5/4	Nil	co, cr	Fr	fi, ma	v.st	sm, cl
	C1	10-50	17.8	46.6	11.4	42.0	SC	10R4/6	7.5YR 8/6	sab	Hd	fi, ma	Nil	sm, cl
	C2	50-65	62.5	46.6	11.4	42.0	SC	2.5YR 4/6	10YR 8/6	m	M	mx, ma	v.st	sm, cl
	C3	65-170	10.7	42.6	5.4	52.0	C	2.5YR 3/6	2.5Y 8/4	sab	Hd	mx, fi	Nil	-

ma= many, fa = faint, fc= fine crumbs, sab= sub-angular blocky, co= coarse, cr= crumb, m= massive, md= medium, SCL= sandy-clay-loam, LC= Loamy-clay, SL= Sandy-loam, CL=Clay-loam, C= Clay, fr= friable, hd= hard, fm = firm, fi= fine, vfw = very few, mx= mixed, sm= smooth, cl= clear, df =diffuse, v.st= very ston.

They possess appreciable amount of loose ferruginous and Fe/Mn concretions at depth from 92 cm. The soils of Mapping Unit B was classified

**Table 3.** Chemical properties of the soils of the study area.

Profile	Hor	Depth cm	pH H <sub>2</sub> O	T.N	O.C	Av.p	Exch Acid	Ca	Mg	K	Na	ECEC	ECEC/Clay	ESP	B. Sat	Fe	Mn	Zn	Cu
				g/kg	mg/kg	cmol/kg					%					mg/kg			
A	Ap	0-17	7.0	0.22	2.45	2.02	0.4	1.6	1.9	0.1	1.5	5.4	51.1	29.5	92.61	221.0	133.0	1.4	10.8
	AB	17-36	6.2	0.23	2.15	10.24	0.7	0.5	0.8	0.1	1.6	3.6	19.6	54.6	80.80	263.0	31.5	1.0	6.4
	Bt1	36-61	6.3	0.20	2.10	7.07	0.6	0.4	0.8	0.1	1.8	3.8	9.3	57.8	84.04	253.0	0.8	1.1	7.0
	Bt2	61-92	6.4	0.21	1.99	11.74	0.6	0.5	0.3	0.0	1.1	2.6	6.1	57.0	76.79	242.0	12.1	1.8	6.2
	Btcv	92-146	6.7	0.21	2.00	10.37	0.6	1.0	0.1	0.0	0.7	2.4	11.7	40.8	75.12	329.0	3.8	1.3	5.8
B	A1	0-14	7.4	0.17	1.68	10.93	0.4	4.3	0.9	0.1	1.7	7.4	69.9	24.2	94.60	225.0	138.0	1.5	7.0
	A2	14-29	6.8	0.16	1.55	0.10	0.6	1.2	1.6	0.1	1.7	5.3	31.7	37.3	88.59	260.0	37.6	2.5	8.8
	Bt1	29-58	6.4	0.16	1.56	0.60	0.5	0.7	3.5	0.1	0.9	5.6	17.2	17.9	91.09	314.0	8.4	3.3	9.7
	Bt2	58-89	6.4	0.15	1.44	12.49	0.5	0.6	0.1	0.1	0.8	2.0	5.9	50.7	75.54	183.0	5.7	7.9	5.6
	Bt3	89-120	6.4	0.17	1.29	7.94	0.6	0.6	0.1	0.1	0.7	1.9	5.6	49.2	68.83	231.0	4.7	5.8	5.5
	Bt4	120-158	6.4	0.10	1.10	4.39	0.6	0.6	0.1	0.0	0.7	2.0	6.9	50.4	69.73	198.0	2.5	6.2	5.4
C	A1	0-17	7.2	0.24	2.23	10.93	0.4	3.1	1.0	0.1	0.6	5.2	48.6	12.8	92.24	153.0	183.0	6.6	6.7
	A2	17-36	7.3	0.20	2.10	8.44	0.4	1.4	1.4	0.0	1.7	4.9	57.3	36.5	91.88	147.0	166.0	7.3	6.9
	B1	36-70	7.0	0.19	2.01	9.18	0.5	0.7	0.7	0.0	1.7	3.8	23.5	53.5	86.68	114.0	185.0	7.4	6.1
	B2	70-92	7.1	0.17	1.99	7.50	0.3	0.9	0.4	0.1	0.7	2.4	13.6	32.5	87.72	407.0	125.0	6.8	6.7
	Bt1	92-136	7.0	0.18	1.68	8.37	0.4	1.1	0.9	0.2	0.7	3.3	16.3	25.9	87.73	325.0	116.0	7.9	7.0
	Btv	136-160	7.2	0.16	1.44	8.87	0.4	1.7	1.2	0.1	0.7	4.1	9.8	19.9	90.27	337.0	26.7	7.4	6.5
D	A	0-15	7.2	0.28	2.68	8.37	0.5	4.0	2.9	0.1	0.7	8.2	41.0	8.5	93.91	311.0	73.2	11.4	6.3
	AB	15-27	6.4	0.22	2.25	7.44	0.8	0.6	0.5	0.1	0.8	2.7	19.1	41.7	70.10	398.0	29.3	8.5	5.3
	Bt1	27-56	6.4	0.19	2.10	6.88	0.7	0.8	0.4	0.1	0.7	2.7	8.3	35.6	73.61	164.0	5.3	7.6	6.1
	Bt2	56-117	6.4	0.27	2.24	6.07	0.8	1.1	0.3	0.1	0.7	3.0	7.1	31.8	73.20	334.0	7.3	7.6	5.0
	Bt3	117-140	6.7	0.20	1.90	8.37	0.9	1.2	0.3	0.1	0.6	3.0	10.7	29.1	69.96	381.0	4.3	7.2	5.6
E	AC	0-10	6.4	0.26	2.46	12.11	0.8	1.7	1.4	0.2	0.7	4.8	21.6	16.5	83.17	117.0	2.5	9.5	6.1
	C1	10-50	6.7	0.19	1.69	8.62	0.5	0.3	0.1	0.1	0.6	1.6	3.7	53.7	67.79	212.0	1.0	9.0	5.6
	C2	50-65	6.4	0.22	1.90	9.87	0.9	0.3	0.1	0.1	0.6	2.0	4.8	50.7	55.33	215.0	1.3	7.9	3.8
	C3	65-170	6.7	0.18	1.55	10.87	0.6	0.2	0.1	0.1	0.6	1.6	3.0	59.0	61.50	210.0	0.3	9.8	4.2

TN= Total nitrogen, OC = Organic carbon.

as lbeshe series. This mapping unit occupy about 18.5% of the total land area and is found on a gently sloping (4 - 6% slope) terrain underlain by

**Table 4.** Summary of pedological classification of the soil mapping units of the study area.

Mapping unit	Local (Moss 1957)	USDA soil taxonomy (Soil Survey Staff, 2014)	WRB (2014)	Size (ha)	Coverage (%)
A	Ilaro Series	Kanhaplic Haplustalf	Plinthic Lixisol (Vetic)	23.85	24.15
B	Ibeshe Series	Typic Kandiustalf	Haplic Lixisol (Loamic, Ochric)	18.29	18.52
C	Kulfo Series	Udic Kandiustalf	Haplic Lixisol (Eutric)	8.81	8.92
D	Molo Series	Rhodic Kandiustalf	Rhodic Lixisol (Hypereutric)	19.72	19.97
E	Otteyi Series (Shallow variation)	Lithic Haplustept	Leptic Cambisol (Geoabruptic)	28.08	28.44

ferruginous sandstone parent materials of the Eocene age and is located at the middle slopes of disintegrating laterite caps. The soils are well drained, deep and had no laterite or ironstone within the profile depth. Consistency is friable to hard (dry) with sub-angular blocky structure throughout the profile except the A horizon. The colour ranges from greyish brown (10YR 5/2) at the top to yellowish red (5YR 4/6) at the subsoil with good profile development evidenced from the clay illuviation down the profile.

The soils represented by Mapping Unit C was classified as Kulfo Series and occupies about 8.92% of the total land area and is found mainly at the lower slope positions. The soils are fairly well drained and deep. Fe-rich variegated mottling suggesting redox reactions occasioned by periodic moisture saturation were noticed at depths below 140 cm. Consistency is friable (moist) almost throughout the profile. The colour ranges from dark brown (7.5YR 3/2) at the top to yellowish red (5YR 5/6) at the subsoil. Mapping Unit D was classified as Molo Series and it occupies about 19.97% of the total land area. The soils are well drained and deep with no laterite or plinthite within the profile depth. Consistency is friable to hard (dry) with sub-angular blocky structure throughout the profile except the A horizon. The colour ranges from dark greyish brown (10YR 4/2) at the top to red (2.5 YR 5/8) at

the subsoil. A higher clay content at the subsoil than the top is as a result of pedogenetic processes (especially clay migration) was observed, leading to the formation kandic subsoil horizon.

Mapping Unit E which was classified as Otteyi Series (shallow variation) covers about 28.4% of the land mass and was classified as Otteyi Series (Shallow variation). The soils occupy the hill crests of the laterite and ironstone capped almost flat upper slope positions on the landscape. They are well drained soils formed from sandstone parent materials. The soil surface is characterized by ironstone rubbles sometimes of boulder sizes. The soil colour ranges from dark grayish brown (10YR 5/4) becoming dark red (2.5YR 3/6) with highly ferruginised mottled clay under the pan rubble. The textural class of the fine earth materials ranges from sandy clay loam increasing in clay content to become clay with depth. The gravel content is high ranging from 10.7 to 31.5%.

#### Soil chemical characteristics

The soil chemical characteristics are as presented in Table 3. Ilaro Series is generally slightly acidic to neutral in reaction (pH 6.2 - 7.0) with high base saturation (75.12 - 92.61%). The ECEC is very low (2.4 - 5.4 cmol/kg), while the organic carbon is

moderate (19.90 - 24.50 g/kg); the highest value being at the upper horizons, decreasing with depth. Ibeshe Series soils are generally slightly acidic to neutral in reaction (pH 6.4 - 7.4) with the lowest acidity at the surface. Base saturation is high (69.73 - 94.60%) and the ECEC is very low to moderate (1.90 - 7.4 cmol/kg), while the organic carbon is low (11.00 - 16.50 g/kg); the highest value being at the upper horizons, decreasing with depth. The soil reaction in Kulfo is mostly neutral (pH 7.0 - 7.3). Base saturation is high (86.68 - 92.24%) and the ECEC is low ranging from 2.4 to 5.2 cmol/kg, while the organic carbon is relatively low (14.40 - 22.23 g/kg); the highest value being at the upper horizons as expected, decreasing with depth. The soils in Molo Series (Mapping Unit D) are slightly acidic (pH 6.4 - 7.2) with acidity increasing with depth. The topsoil is relatively richer in organic matter content (26.8 g/kg) than the subsoil (4). Nitrogen and phosphorus content are 2.8 g/kg and 8.74 mg/kg, respectively at the topsoil. They are also generally low in exchange cations even though high (>50%) in base saturation. The micro-nutrient contents are low for Cu and Zn but adequate for Mn and Fe. In addition to the aforementioned, they have a texture of sandy loam of 30 cm or more thick within 50 cm of the soil surface. The soils of Otteyi Series are slightly acidic (pH 6.4 - 6.7); moderately high in organic carbon content (24.6 g/kg) at the

surface decreasing with depth to 15.5 g/kg. The ECEC is low (1.60 - 4.8 cmol/kg) also decreasing with depth.

### Taxonomic classification

At the higher categories the soils of Mapping Unit A was classified as Plinthic Lixisol (Vetic) (FAO/IUSS, 2014) and Kanhaplic Haplustalf (Soil Survey Staff, 2014). They experience ustic moisture regime with argillic horizons at the subsoil. At the lower category they are classified as Ilaro series (Moss, 1957). They display distinct mottled clay structure, in addition to the attributes described. The soils of Unit B was classified as at WRB categories as Haplic Lixisol (Loamic, Ochric) (FAO/IUSS, 2014) and Typic Kandiuustalf (Soil Survey Staff, 2014). They possess low activity clays (1:1 lattice clay minerals) with more than 50% base saturation in the major part between 20 and 100 cm from the soil surface and 80% or more in some layers within 100 cm of the soil surface. They experience ustic moisture regime with a Kandic B horizons at the subsoil. At the lower category they are classified as Ibeshe series (Moss, 1957).

The soils of Mapping Unit C are classified as Haplic Lixisol (Loamic, Ochric) (FAO/IUSS, 2014) and Udic Kandiuustalf (Soil Survey Staff, 2014). They possess low activity clays (1:1 lattice clay minerals) with more than 50% base saturation in the major part between 20 and 100 cm from the soil surface and 80% or more in some layers within 100 cm of the soil surface. They experience ustic moisture regime with a Kandic B horizons at the subsoil. At the lower category, they are classified as Kulfo series (Moss, 1957). They are therefore classified as Molo series (Moss, 1957); Rhodic Lixisol (Hypereutric) (FAO/IUSS, 2014) and Rhodic Kandiuustalf (Soil Survey Staff, 2014). The ironstone pan rubble in this soil is characteristically hard and somewhat metallic and occurs mostly at the surface making effective soil depth in this unit less than 15 cm. Hence, they are classified at the series level as Oteyyi Series (Shallow variation) (Moss, 1957). The soils are classified as Leptic Cambisol (Geoabruptic) (FAO/IUSS, 2014) and Lithic Haplustept in the USDA soil taxonomy.

### Land capability classification (LCC)

A summary of the classification of the mapping units into capability classes is presented in Table 5 while the land capability map is presented in Figure 2. Soil Mapping Units B and D (Ibeshe and Molo Series) are grouped into Capability Unit IIf. This unit occupies about 60% of the total area of site 1 (Figure 2). The soils are deep, occupying gentle to almost flat positions on the landscape with little or no risk of accelerated erosion and runoff. The major limitation is that of fertility (f). The soils do not have problems of stoniness and excessive gravel

content to limit plant roots proliferation. The effective soil depth of the unit is more than 160 cm. Thus, for most arable and tree crops hard pan is not a limiting factor. For oil palm, the roots are essentially fibrous and can exploit the soil laterally and also due to the fact that the greatest quantity of the roots is to be found between soil depths of 20 and 60 cm, and most of the absorption of nutrients have been known to be through the quaternary roots and absorbing tips of the primary, secondary and tertiary roots to this depth. The soils can be tilled and ridged for cassava, yam and maize though mechanical tillage. Though, the slope gradients are not too steep to warrant high susceptibility to erosion, tillage should be done across the slope contour to prevent erosion. If nutrients as the only limiting factor this unit could be supplied through sound fertility management, it is capable of optimal arable crop production.

Soil Mapping Unit A (Ilaro Series) is classified into Capability Unit IIdf. This is moderately good unit for crop production with effective soil depth (d) (<100 cm), and low fertility (f) being the major limiting factors, for arable crop production. The capability unit occupies about 24.15% of the land area (Figure 2). It is concentrated in the south central portions of the land area. Maintenance of soil surface cover in form of cover crops or green mulch and manual land clearing will go a long way to reduce the possibility of erosion on the unit. Though, this land has an ironstone layer, it occurs in most parts of the unit below 80 cm depth. Thus, for most arable crops, except tap rooted tree crops, the hard pan may not be a serious limiting factor, since most of the plant's feeder roots are concentrated in the upper 60 cm. Some form of moisture stress may be expected at the height of dry season. This can, however, be minimized by the application of green or dry mulch. The limiting factor identified are mild and readily be corrected through management practices.

Mapping Unit C (Kulfo Series) was grouped into Capability Unit IIIfew. Fertility (f), erosion (e) and possibility of wetness at the peak of high rainfall are the major limiting factors. The unit is marginally capable for arable but is good for tree crop production. Due to the torrential nature of the rainfall in the area, coupled with sloping (6-8%) nature of the area, it is predisposed to accelerated erosion if large tracts are opened up at once. The site is recommended for tree crop production like oil palm which can keep the soils covered and prevent erosion. This unit because of the periodic high water table may make an excellent area if supplementary water could be provided, for off-season vegetable production. Soil surface cover should be maintained as much as possible.

### Fertility capability classification

The fertility capability classification rating as obtained by adding the dominant textural class of the type, substrata



**Table 5.** Land capability classification of the mapping units.

Mapping unit	Characteristics/Limitations	Capability unit
A	Moderate capability, with low fertility level and soil effective depth <100 cm as the main limitations	IIfd
B	Low to medium fertility	IIf
C	Moderate liability to run-off and low to medium soil fertility and possibility of periodic high water table	IIIfew
D	Low to medium fertility	IIf
E	Very shallow soil depth, stoniness, low fertility and possibility of erosion	VIdef

II = Capability class II (Moderately Arable); III = Capability class III (Marginally Arable); VI = Capability class VI (Non-Arable except for few tree crops or rangeland); f = Fertility deficiency; e = Erosion limitation; d = Effective soil depth limitation (indurated hard pan layer); w = wetness, possibility of seasonal high water table; s = stoniness.

**Table 6.** Fertility capability classification (FCC) of the soils of the study area.

Mapping unit	Soil series	Size (ha)	Coverage (%)	Horizon (depth)	Textural class	Type	Type/ Substrata	K Reserve (k)	CEC (e)	Rooting (r)	Na sat (n)	FCC
A	Ilaro Series	23.85	24.15	0-17	SL	L	-	0.1	5.4	-	-	LCke
				17-36	SL	L	-	0.1	3.6			
				36-61	SC	C	C	0.1	3.8			
B	Ibeshe Series	18.29	18.52	0-14	SL	L	-	0.1	7.4	-	-	SLke
				14- 29	SCL	C	-	0.1	5.3			
				29-58	-	-	-	0.1	5.6			
C	Kulfo Series	8.81	8.92	0-17	SL	L	-	0.1	5.2	-	-	SLke
				17-36	LS	-	S	0	4.9			
				36-70	SL	-	S	0	3.8			
D	Molo Series	19.72	19.97	0-15	SCL	L	-	0.1	8.2	-	-	Lke
				15-27	SL	-	L	0.1	2.7			
				27-56	SCL	-	L	0.1	2.7			
E	Otteyi Series	28.08	28.44	0-10	SCL	L	-	0.2	4.8	***		Lr***
				10-50	SCL	-	L	0.1	1.6			

Coarse loamy top soils; sandy loams. L- Fine loamy top soils; sandy clay loams and loams. Fine clayey sub-soils; sandy clay to clay. L - Fine loamy sub-soil; sandy clay loams and loams Condition Modifiers. k- Soils having very low amounts of potassium (exchangeable K less than 0.2cmol/100g soil). e- Soils with low CEC in the plow layer. r- soils with root restricting layers such as gravel or hard pan.

and the limiting condition modifiers for each soil series and this is shown in Table 6. Ilaro Series

had a Loamy starata with a clayey substarata types. The type is the dominant textural class

within 0 to 25 cm of the soil series while the substrata represent the dominant textural class at

25 to 50 cm or the plow layer. A CEC value of <15 cmol/kg indicates low CEC and K value of <0.2 cmol/100 g of soil indicates K deficiency. The low CEC and low K reserves were common to almost all the Pedons in the study area. Otteyi Series had serious root restriction limitations resulting from pan rubbles on or close to the soil surface. This renders this pedon inappropriate for cropping.

## DISCUSSION

The soils of the study are generally sandy loam at the top with the clay content generally increasing with depth and were classified as Kanhaplic Haplustalf, Typic Kandiuustalf, Udic Kandiuustalf, Rhodic Kandiuustalf, and Lithic Haplustepl in the USDA soil classification system. In the order level of classification, 71.56% of the soils are Alfisols and 28.44% Inceptisols. The difference between Typic Kandiuustalf and Udic Kandiuustalf is that though they both have a kandic B horizon at the subsoil, Typic Kandiuustalf experiences an ustic moisture regime whereas Udic Kandiuustalf experiences a higher soil moisture (at a lower slope position) similar to udic moisture regime described as a humid climate with about eight to nine months of rainfall in a year (Ojanuga, 2006). In terms of colour, the soils are characterized by dark brown to dark red, greyish-brown to yellowish-red, dark-brown to yellowish-red, dark greyish brown to red and dark greyish brown to dark red. The yellowish red, red and dark red coloration indicates the presence of iron oxides; dark brown color indicates high organic matter content (Brady and Weil, 1999).

The soils are generally slightly acidic to neutral (pH 6.2 - 7.4). Soil acidity can affect nutrient availability, herbicide persistence and toxicity of heavy metal, all of which can adversely crop production (Reeves and Liebig, 2016). The degree of leaching, nature of parent material, intensity of cropping going on in the soils are likely factors affecting the pH of the soil (Leibig et al., 2004). On a general note, the fertility status of the soils is higher at the upper horizons than the sub-soils which aligns with previous findings (Sharu et al., 2013, Belachew and Abera, 2010). The nitrogen status is higher than the critical level of 1.5 g/kg (Fontes and Ronchi, 2002) in about 90% of the land area. However, it must be noted that N is a dynamic nutrient and the present status is a result of organic matter accumulation on the surface soils which mineralizes rapidly on land clearing. Available P is generally deficient as less than 10% of the land area contains the required critical range of 15 to 45 mg/kg for sustainable arable cropping (Weaver and Wong, 2011). The soils are generally deficient in potassium, having values less than the critical level of 0.2 to 2.6 cmol/kg (Anderson et al., 2013) throughout the whole land area. The ECEC values of the soils are above the minimum standard of 4.0 cmol/kg in all portions of the land area owing principally

to Calcium levels that are generally higher than the minimum requirement of 3.8 cmol/kg in all the soils. These according to Crespo et al. (2017) are dependent on such parameters as pH and organic matter content of the soils. The organic carbon levels of the soils are low ranging from 1.1 to 2.68 g/kg which is far below the critical level of 30 g/kg proposed by ISRIC (1995). The low organic carbon might have resulted from the high mineralization rate and cropping history of the area. The micro-nutrients (Mn, Cu and Zn) are at sufficiency level only at the top soil. Their critical values are 20 to 25, 1.2 to 2.0 and 3.0 to 3.45 mg/kg, respectively. The iron (Fe) content of the soils are however very high, far above the critical value of 161 mg/kg (Feiziasl et al., 2009; Crespo et al., 2017). Those nutrient elements that are below the critical levels need be supplied through deliberate fertilizer application to build up their levels in the soil. It was observed that Mapping Units A, B, and D are moderately capable of supporting arable cropping with limitations such as low fertility and soil effective depth for Mapping Unit A, low to medium fertility for Mapping Units B and D. Mapping Unit C is marginally capable with limitations such as moderate liability to run-off and low to medium, soil fertility and possibility of periodic high water table (wetness) whereas Mapping Unit E is non-arable with limitations such as very shallow soil depth, stoniness, low fertility and possibility of erosion.

Based on fertility capability classification, of the seventeen different condition modifiers used in the evaluation, potassium deficiency ( $k^- < 0.20$  cmol/100 g) and low cation exchange capacity ( $e^- < 15$  cmol/kg) occurred in 100% of the soils studied. The mapping units were thus classified as LCke, SLke, SLke, Lke and Lr\*\*\* for Ilaro, Ibeshe, Kulfo, Molo and Otteyi Series, respectively. Potassium deficiency occurred in all soils because majority of the soils are very high in sand content, the sandy texture of the soils as well as high concentration of the gravel in the soil must have encouraged the leaching of the available soil nutrients as  $K^+$  which are highly soluble (Datnoff, 2007; Senjobi, 2007). Potassium plays a lot of roles in plants such as protein synthesis, opening and closing of stomata, activation of some enzymes, phloem solute transport, and maintenance of cation: anion balance in the cytosol and vacuole, a deficiency in K will impair a plants ability to maintain the processes. The low CEC of the soil is also attributed to the sandy texture of the soils. The CEC of soils influence soil structure stability, nutrient availability, soil pH and other ameliorants (Hazleton and Murphy, 2007). Soils with low CEC are more likely to develop deficiencies in K, Mg and other cations (CUCE, 2007).

## Conclusion

The soils generally are slightly acidic to neutral and of low fertility status; all the soils are deficient in exchangeable

potassium and low CEC. Hence, the major management problems of the soils which are relevant to agricultural production are those related to the maintenance of soil fertility under continuous cropping. The productivity of the soils can be improved through the judicious use of organic and inorganic fertilizers. Land use type and land capability need to be considered in taking appropriate approach to soil rehabilitation or improvement for agricultural uses in these soils. Organic matter management is essential for good crop production.

Organic matter accumulation through green and/or dry mulching should be encouraged. This will enhance the physical properties (bulk density, infiltration rate, hydraulic conductivity, water holding capacity, etc.) of the soils. The chemical fertility will also be enhanced as the organic carbon increases leading to the improvement of the status of nutrient elements in the soil.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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