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Characterization, classification and agricultural potentials of some coastal plain sand derived soils in Lagos State

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ABSTRACT

Detailed soil surveys were carried out on a total of 194.5 hectares of the land at Igbokuta and Ibomwon areas in Ikorodu and Epe local government areas of Lagos state. Grid survey method was employed, and mapping units were delineated based on soil morphological characteristics examined at an interval of 70m along transects that were laid 100m apart. The soils were classified according to local soil series, USDA soil taxonomy and World Reference Base (WRB) soil classification methods. The identified soils were evaluated using the Fertility Capability Classification (FCC). Six mapping units were identified in this study and were classified as Inceptisols and Ultisols. A total of about 77.68% of the soils were classified as Ultisols while about 22.32% of the soils were classified as Inceptisols. The land capability classification shows that most of the soils belong to class II, which has excellent potential for arable crop production but may require careful management as a result of some limitations. Fertility classification of the soils into various FCC units revealed that the soil strata type and subtypes are mainly loamy (L) to sandy (S). Only one of the soil types which was Pakoto series (Plinthic Kandiudult) with FCC unit LRkr^{++} was found to be non-arable due to severe limitations of rock outcrops and very high gravel contents. The soils generally require management practices such as application of organic manure, fertilizer and liming to mitigate the fertility limitations. Other management strategies such as drainage and flood control would improve the productivity of the areas prone to waterlogging for arable crop production.

1.0. Introduction

Recently, economic and demographic realities in Nigeria and sub-Saharan Africa has necessitated a need for the rapid increase in food production where demand for food and fibre has witnessed an upsurge (Behzad *et al*., 2009; Ande, 2011). Meeting the increasing demand for food requires either the expansion of areas of cultivation or the intensification of production to increase the yield per unit area of land. Since the increase in population has also reduced per capita land availability (Ogunkunle, 2016), intensification of production systems seems to be the best option. This option, however, requires an in-depth knowledge of the characteristics, quality, distribution and potentials of land/soil resources.

A significant problem of agricultural development in Nigeria is inadequate knowledge and appraisal of suitability of parcels of land for agricultural production. The result is poor farm management practices, low yield and high cost of production (Aderonke and Gbadegesin, 2013). The knowledge of soil limitations arising from land evaluation reports aims at ameliorating such limitations before, or during the cropping period (Lin *et al.,* 2005). Therefore, soil, as the primary medium for cultivation, needs to be assessed (surveyed/characterized) scientifically. The performance assessment is based on matching qualities of different land units in a specific area with the requirements of actual or potential land utilization types. This assessment results in the classification of lands as to their suitability to produce specific crops or combination of crops (Ezeaku, 2011). It also enables management guidelines to promote more sustainable use of the soil and environmental resources (Maniyunda *et al.,* 2007).

Lagos state is one of the areas with the highest population density, and yet, it has the smallest land areas. It has been observed that the productivity of Nigerian soil is decreasing and the lands have been utilized intensively for all purposes, regardless of its suitability and capability functions thereby resulting in land degradation and altering of the national ecological conservatory balances in the landscape (Senjobi and Ogunkunle, 2011). The rapid expansion of Lagos with various competing needs for land, therefore, necessitates an urgent inventory of the soil resources. This study was conducted to characterize the soils at selected sites in Lagos state, classify the soils using local and international classification systems and evaluate the potentials of the different soil types for sustainable arable crop production.

2.0. Materials and Methods

2.1. Description of the study area

The study was carried out in June 2015 on a total of 194.5 hectares of land at Igbokuta and Ibomwon communities in Ikorodu and Epe local government areas of Lagos state respectively (Fig. 1) The study site at Igbokuta village is defined within the Latitudes 6°37'51.10"N - 6°38'1.18"N and Longitudes 3°38'38.40"E - 3°38'53.50"E while that of Ibomwon village is within Latitudes 6° 40' 12.50" N - 6° 40' 34.58" N and Longitudes 3°56' 38.14" E - 3° 56' 55.29" E. (Fig.1). The general geology of the area consists of sandstones with shales, clays and lignite of the Benin Formation (Ojanuga, 2006). The specific study sites were underlain by recent quaternary littoral sandy alluvium and coastal plain sands (Adelana *et al*., 2008). The study area has an average annual rainfall of 1554 mm distributed in a bimodal pattern with the most torrential rains falling between April to July and a weaker rainfall in October and November. The mean maximum and minimum temperatures are 32°C and 18 °C, respectively (NIMET, 2016).

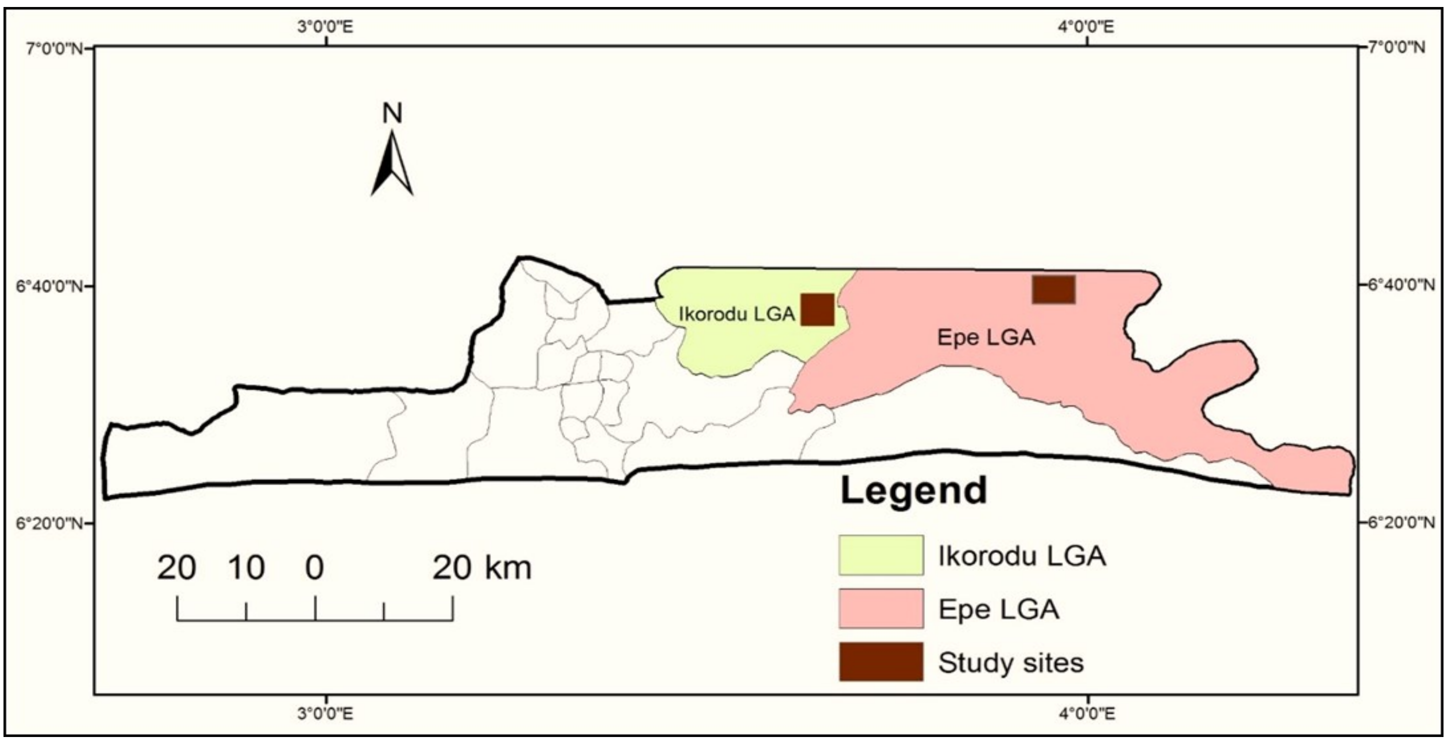

Fig. 1: Location map of study sites in Lagos State

2.2. Field Survey

A grid method of soil survey was adopted for the detailed land resource survey. Transects were laid out at 80m apart, and auger observations were taken at 70m interval along transects thus ensuring one or two examination points per hectare of the land. Examination points were predetermined in a Geographic Information System (GIS) environment and the co-ordinates were pre-loaded into a Global Positioning System (GPS) devise with which the points were located on the field. Auger borings were made at the pre-determined points. Relevant soil morphological properties such as texture, colour (using Munsell soil colour chart), consistency, mottles, cementations etc. were examined at 0-15 cm, 15-30 cm, 30-60 cm and 60-90cm depths at each examination point. Based on these, soil mapping units were identified, and each of the mapping units was further examined with modal soil profiles measuring 2 x 1.5 m dug up to 1.8m (where possible). The profiles were described according to the FAO (1990) guidelines.

2.3. Soil Sampling

Soil samples were collected at genetic horizons at various depths of the soil profiles for laboratory analysis. Also, surface soil samples from 0-30 cm depth from the auger examination points were collected. The soil samples are air-dried and crushed with mortar and pestle to break hard clods soil particles to ease passage through a 2mm sieves for physic-chemical analysis and 0.5mm sieves for organic carbon and total Nitrogen determination while the gravel content and the ratio of the gravel portion (>2mm diameter) for all the soil samples were determined and was calculated as a per cent of total air-dried soil.

2.4. Laboratory Analysis

The soil samples were analyzed for particle size distribution, organic carbon, soil pH (H_2O and KCL), Total nitrogen, Available phosphorus, exchangeable bases, i.e. Magnesium (Mg), Calcium (Ca), Potassium (K) and Sodium (Na), exchangeable acidity and Aluminium, Extractable Micronutrients, i.e. Manganese (Mn), Zinc (Zn), Copper (Cu) and Iron (Fe), Effective Cation Exchange Capacity (ECEC), Percentage Base Saturation. All parameters were determined by standard procedures as described in Methods of soil analysis, part 3 Soil Chemistry (1996). Effective Cation Exchange Capacity (ECEC) was determined by summation, while exchangeable sodium and base saturation were calculated.

2.5. Soil Classification and land evaluation

The soils were classified using the local series classification of soils on the sedimentary origin of Moss (1957). The local classification was correlated with the USDA Soil Taxonomy (Soil Survey Staff, 2014) and the FAO/IUSS World Reference Base classification system (FAO, 2014). Land characteristics with environmental factors are employed as diagnostic factors of land quality. The land qualities such as nutrient supply, erosion hazard, the potential for mechanization, etc. of the pedons were used for assessment for Land Capability Classification (LCC) and Fertility Capability Classification (FCC) units according to the Sanchez *et al.* (2003) for agricultural land use for the study sites.

3.0. Results

Six soil mapping units were identified and were denoted with alphabets A, B, C, D, E and F in the two surveyed sites, the classification and description of each mapping unit is presented in Table 1. The colour of the soils differ in all the mappings, the soil colour range from brown (7.5 YR 4/4) to dark red (2.5YR 4/8) with no mottles in all the profiles for mapping unit A, dark greyish brown (10YR 4/2) to yellowish-red (5YR 5/8) with no mottles for mapping unit B, light yellowish brown (2.5Y 6/3) to very dark greyish brown (10YR 3/2) with mottles at the surface horizon ranging from yellowish-brown (10YR 5/8) too strong brown (7.5YR 5/8) for mapping unit C, dark greyish brown (10YR 4/2) too strong brown (7.5YR 5/8) with no mottles for mapping unit D, very dark brown (10YR 2/2) to grey (5Y 6/1) with no mottles for mapping unit E and black (10YR 2/1) to reddish yellow (7.5YR 6/6) with no mottles for mapping unit F. the structure of all the mapping units for the profiles range from coarse crumb to subangular blocky and the consistency range from friable to firm when moist.

The physical properties of the study sites are presented in Table 2. For all the profiles, the texture of the soil range from sandy loam to sandy clay in mapping units A and D, loamy sand to sandy loam in mapping unit B, loamy sand to sandy clay loam in mapping unit C, sandy loam to sandy clay loam in mapping unit E and sandy loam to clay in mapping unit F. for all the mapping units, the sand fraction range from 446- 838 g/kg, silt fraction range from 14-194 g/kg while clay fraction range from 74- 420 g/kg

Table 1: classification and description of each mapping unit of soils in the study areas

Mapping unit	Soil Series (Moss, 1957)	Coverage Area (%)	Soil Taxonomy (Soil Survey Staff, 2014)	WRB (FAO/ISRC/IUSS 2014)
A	Alagba	23.91	Rhodic Hapludult	Haplic Acrisol (Rhodic)
B	Dodokindo	12.78	Plinthic Kandiudult	Petroplinthic Acrisol (Vertic)
C	Idesan	2.53	Typic Endoaquept	Gleyic Fluvisol (Oxyaquic)
D	Owode	34.74	Typic Kandiudult	Haplic Acrisol (Nitic)
E	Atan	19.79	Fluvaquentic Endoaquept	Gleyic Fluvisol (Oxyaquic)
F	Pakoto	6.25	Plinthic Kandiudult	Pisoplinthic Acrisol (Vertic)

Table 2: Physical Properties of Soils of the sites at Ikorodu and Epe

Profile No	Map Unit	Soil series	Horizon	Depth (cm)	Sand	Silt	Clay	Texture	ECEC/Clay (%)
						(g/kg)			
KRD 1	A	Alagba	A	0-14	706	134	160	SL	22.25
			AB	14-41	626	54	320	SCL	9.16
			Bt1	41-67	606	34	360	SC	7.39
			Bt2	67-103	586	34	380	SC	5.97
			Bt3	103-137	566	14	420	SC	5.17
			Bt4	137-180	546	34	420	SC	5.26
KRD 2	B	Dodokindo	A	0-13	832	74	74	LS	95.27
			AB	13-33	812	94	94	LS	57.23
			Bt1	33-57	732	174	94	SL	51.06
			Bt2	57-98	732	194	74	SL	55.95
			Bt3	98-150	732	174	94	SL	41.81
KRD 3	C	Idesan	A1	0-10	812	94	94	LS	45.74
			A2	10-27	812	114	74	LS	18.65
			Bw1	27-55	772	134	94	SL	9.89
			Bw2	55-85	752	134	114	SL	9.65
			Bw3	85-107	692	34	274	SCL	4.31
EP1	D	Owode	A	0-19	838	38	124	SL	13.57
			AB	19-35	638	58	304	SCL	20.26
			Bt1	35-66	638	38	324	SCL	19.77
			Bt2	66-105	578	58	364	SC	14.91
EP2	E	Atan	Ah	0-18	758	118	124	SL	16.19
			Bg1	18-39	838	58	104	LS	1.91
			Bg2	39-75	706	94	200	SCL	8.25
			Bt3	75-85	666	78	260	SCL	14.22
EP3	F	Pakoto	A	0-10	746	114	140	SL	29.00
			AB	10-30	586	114	300	SCL	29.28
			Bt1	30-53	546	94	360	SC	44.97
			Bt2c	53-75	546	94	360	SC	56.40
			Bt3	75-105	446	134	420	C	47.74
			Bt4v	105-150	446	154	400	C	50.19

3.1. Chemical properties

The chemical properties of the two surveyed sites are represented in Table 3. The soils in all the mapping units have a pH ranging from 3.9- 6.4 with the surface horizon of mapping units D having the highest pH(6.4) and the lowest horizon of mapping units E having the lowest pH (3.9). The pH decreases irregularly down the profile in all the mapping units except for mapping units E with a regular decrease in pH with depth and tends to be more acidic. Organic carbon ranges from 3.2- 70.80g/kg with the surface horizons having high organic carbon contents in all the mapping units. Mapping units D has the highest organic carbon in all its horizons which may be due to planting activities taken place at the time of the study, and there is a regular decrease of the organic carbon content of the soil with depth in all the mapping units except for mapping unit C with irregular decrease with depth. Available P ranges from 0.04 to 4.73 cmol/kg, Mg ranges from 0.02- 3.17 cmol/kg, K ranges from 0.04- 0.34cmol/kg and Na ranges from 0.14- 0.26 cmol/kg. The lowest horizon of mapping units E and F are noticed to have a high amount of K.

Table 3: Chemical Properties of Soils in the study sites at Ikorodu and Epe

Profile No	Mapping unit	Soil series	Depth (cm)	pH (1:1) (KCl)	pH (1:1) (H_2O)	Org C (g/kg)	Total N (g/kg)	Av P (mg/kg)	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	Ex Ac. (cmol/kg)	ECEC (cmol/kg)	B/Sat (%)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
KRD 1	A	Alagba	0-14	4.6	5.3	14.20	2.20	0.22	1.67	0.95	0.16	0.17	0.6	3.56	83.15	20.1	23.3	0.7	8.0
			14-41	4.6	5.3	8.90	1.50	0.08	0.72	0.54	0.10	0.18	1.4	2.93	52.22	2.1	27.4	0.4	3.2
			41-67	4.0	4.7	6.40	1.50	0.07	0.15	0.34	0.18	0.17	1.8	2.66	32.33	2.0	20.2	0.6	2.8
			67-103	3.8	4.5	6.60	0.90	0.11	0.17	0.24	0.09	0.18	1.6	2.27	29.52	1.0	18.8	0.6	2.8
			103-137	4.0	4.7	4.20	0.80	0.04	0.19	0.29	0.12	0.18	1.4	2.17	35.48	1.1	16.4	0.8	2.7
			137-180	4.3	5.0	3.20	0.70	0.04	0.23	0.31	0.07	0.21	1.4	2.21	36.65	1.0	17.5	0.4	2.5
KRD 2	B	Do-dokindo	0-13	4.4	5.1	27.80	3.10	0.12	1.48	0.66	0.10	0.20	4.6	7.05	34.75	4.3	80.1	0.5	4.5
			13-33	4.5	5.2	12.70	3.10	0.19	0.10	0.17	0.11	0.21	4.8	5.38	10.80	1.1	70.2	0.3	2.5
			33-57	4.4	5.1	9.30	2.20	0.17	0.09	0.20	0.13	0.20	4.2	4.80	12.86	1.1	35.5	0.3	2.2
			57-98	4.4	5.1	5.90	1.40	0.17	0.04	0.08	0.07	0.15	3.8	4.14	8.21	0.1	15.6	0.4	2.4
			98-150	4.3	5.0	3.20	0.80	0.05	0.04	0.07	0.06	0.16	3.6	3.93	5.85	0.1	17.5	0.3	2.2
KRD 3	C	Idesan	0-10	4.6	5.3	20.10	4.90	0.29	1.76	1.69	0.07	0.18	0.6	4.30	86.05	24.6	43.3	0.6	10.7
			10-27	4.7	5.4	7.40	1.80	0.10	0.06	0.07	0.04	0.17	1.0	1.38	38.00	1.0	98.3	0.9	4.0
			27-55	4.8	5.2	3.80	1.00	0.07	0.05	0.06	0.04	0.18	0.6	0.93	35.48	0.1	76.8	0.7	2.7
			55-85	4.4	5.1	4.70	1.10	0.09	0.05	0.05	0.04	0.16	0.8	1.10	27.27	1.1	76.7	1.0	2.7
			85-107	4.6	5.3	3.80	1.00	0.09	0.06	0.06	0.05	0.18	0.8	1.18	32.20	0.1	95.6	1.2	2.7
EP1	D	Owode	0-19	6.4	5.5	70.80	3.01	7.35	4.73	3.17	0.24	0.16	0.6	8.92	93.05	12.4	73.6	0.5	6.3
			19-35	5.4	5.0	60.10	1.11	7.28	1.63	0.23	0.16	0.14	6.6	8.77	24.65	1.1	65.6	0.2	3.6
			35-66	5.5	4.9	36.70	0.73	3.81	1.31	0.09	0.16	0.16	7.2	8.92	19.27	1.0	48.3	0.1	3.7
			66-105	5.3	4.9	10.90	0.01	3.93	0.61	0.10	0.14	0.14	6.0	6.99	14.10	1.0	17.3	0.1	3.6
			105-155	5.7	4.8	9.50	0.01	4.10	0.61	0.22	0.15	0.16	6.4	7.54	14.99	1.0	9.4	0.1	3.5
EP2	E	Atan	0-18	5.1	4.6	66.40	7.12	6.89	1.62	0.18	0.19	0.16	7.0	9.16	23.49	6.4	104.4	0.4	5.0
			18-39	5.1	4.4	54.40	2.33	7.15	0.98	0.21	0.14	0.17	1.0	2.51	60.10	1.0	22.3	0.2	3.8
			39-75	4.5	4.0	37.80	4.31	3.93	0.63	0.05	0.18	0.26	2.0	3.13	35.86	1.1	27.4	0.7	4.5
			75-85	3.9	3.4	7.00	4.61	0.73	0.62	0.03	0.31	0.22	1.8	2.98	39.50	17.4	98.6	0.6	8.1
EP3	F	Pakoto	0-10	5.8	5.2	31.90	4.31	3.31	0.89	0.92	0.15	0.18	5.8	7.94	26.84	2.2	58.4	0.3	3.9
			10-30	5.8	5.1	13.50	1.50	1.40	0.62	0.02	0.14	0.16	6.4	7.36	12.74	1.1	45.7	0.2	3.8
			30-53	4.7	4.3	11.60	1.42	1.20	0.60	0.03	0.16	0.17	5.6	6.56	14.62	1.2	40.2	0.2	3.9
			53-75	4.7	4.4	10.10	0.58	1.05	0.42	0.02	0.18	0.19	4.8	5.62	14.35	3.3	18.3	0.2	3.8
			75-105	4.8	4.5	8.40	0.35	0.88	0.52	0.03	0.15	0.16	3.6	4.45	18.95	1.1	16.8	0.1	3.7
			105-150	4.8	4.4	6.70	0.01	0.70	0.32	0.05	0.31	0.22	1.8	2.69	33.18	7.4	98.6	0.6	8.1

3.2. Land capability classification

All the mapping units are capable of arable crops, as shown in Table 4. Mapping units A and F were grouped into capability subclass IIe with limitations of risk of erosion and low nutrient for both mapping units and gravel content peculiar to mapping units F. Mapping units B and D were grouped into capability subclass IIs with limitation of the low nutrient reserve. In contrast, mapping units C and E were grouped into capability subclass IIIws with limitations of excess wetness and flooding hazard. Soils with sandy loam texture at the surface have low infiltration rate, high water table and soils associated with impeded drainage and waterlogging are prone to excess wetness and flooding hazard.

Table 4: Land capability classification of the mapping units

Mapping Unit	Soil series	Capability class	Major Limitation
A	Alagba	IIe	Risk of erosion, low nutrient
B	Dodokindo	IIs	Low nutrient reserves
C	Idesan	IIIws	Flooding hazard, and excessive wetness
D	Owode	IIs	Low nutrient reserves
E	Atan	IIIws	Flooding hazard, excessive wetness and leaching
F	Pakoto	IIe	Risk of erosion, gravel and low nutrient

3.3. Fertility capability classification

The grouping of the representative mapping units into various fertility capability classification units according to the Sanchez *et al.* (2003) system is shown in Table 5a. FCC units are according to the fertility-related limitations. The top 50cm depth was used to place the soil mapping units into FCC group according to their fertility-related limitations, and the interpretation of the fertility classification is presented in Table 5b. The soils are generally loamy topsoil except for mapping units B and C which have sandy strata type and mapping unit F which has loamy strata type but highly gravelly and may be considered as not perfect for growing crops. According to the FCC interpretations obtained from the study, all the soils have some limiting fertility issues which range from potassium and aluminium deficiency except for mapping units D, which has no fertility limitations. Mapping units A, B, C and E, are acidic. To obtain a high level of soil fertility for arable cropping, the above limitations must be worked on for maximum yield.

Table 5a: classification of soil into their FCC class

mapping units	Soil series	Type	Substrata type	Condition Modifiers a	e	g	k	r	FCC Class
A	Alagba	L	_	*	*	_	*	_	Laek
B	Dodokindo	S	_	*	_	_	*	_	Sak
C	Idesan	S	_	*	*	*	*	_	Saegk
D	Owode	L	_	_	_	_	_	r^{+}	Lr^{+}
E	Atan	L	_	*	_	*	*	r^{+}	$Lagkr^{+}$
F	pakoto	L	R	_	_	_	*	r^{++}	$LRk\ r^{++}$

Table 5b: soil FCC unit's interpretation

Mapping Units	Soil series	FCC Units	Interpretation
A	Alagba	Laek	Loamy topsoil<35% clay, acidic, low nutrient capital reserve (k and Al deficiency)
B	Dodokindo	Sak	Sandy topsoil, acidic, low nutrient capital reserve (k deficiency)
C	Idesan	Saegk	Sandy topsoil, acidic, aquic moisture regime, low nutrient capital reserve(k and Al deficiency)
D	Owode	Lr^{+}	Loamy topsoil<35% clay, gravely
E	Atan	$Lagkr^{+}$	Loamy topsoil<35% clay, acidic, aquic moisture regime, low nutrient capital reserve (k deficiency), gravelly
F	pakoto	$LRk\ r^{++}$	Loamy topsoil<35% clay, rock or hard root restricting layer, low nutrient capital reserve (k deficiency), very gravelly

4.0. Discussion

The soils in mapping unit A are identified a Rhodic Hapludult in the USDA soil taxonomy because it is a soil formed in the humid region with low organic matter content and base saturation less than 50%, it is red coloured soil with acidic soil reaction. The soils are formed from sedimentary parent materials with a udic moisture regime. According to WRB classification, the soil qualifies as Haplic Acrisol (Rhodic) base on the CEC of the soil is < 24 cmol/kg clay in the horizon within ≤ 50 cm and its base saturation is < 50% in the major part between 50 and 100 cm of the soil profile. The soil is classified as Alagba series in the local classification system (Moss, 1957) based on its clay enriched subsoil with no gravel, concretion or hardpan up to the depth of 180 cm. The soil is well-drained with the depth to the water table below the profile depth, the colour ranges from strong brown to dark red, and soil texture ranges from sandy loam to sandy clay throughout the profile.

The soils in mapping unit B have more than 5% (by volume) plinthite in one or more horizons within 150 cm of the soil profile which characterize it as Plinthic Kandiudult according to USDA soil taxonomy. The CEC of the soil is < 24 cmol/kg clay in the horizon within ≤ 50 cm, and its base saturation is < 50% in the major part between 50 and 100 cm of the soil profile, these classify the soil in this mapping unit as Petroplinthic Acrisol (Vertic) in the WRB. It is classified as Dodokindo series in the local classification system (Moss, 1957) with the colour ranging from dark greyish brown to the yellowish red, light-textured surface with marked clay illuviation overlying consistent iron-pan layer that occurs at depths ranging from 90 -110 cm, the slope is straight with slightly undulating topography. It is well-drained with a depth of table water below the profile depth.

The soils in mapping unit C are classified as Typic Endoaquept in the USDA soil taxonomy because the base saturation is less than 50% in some part within 100 cm of the soil profile. The organic carbon decreases irregularly with depth and has gleyic properties throughout and reducing conditions in some parts of every subsurface, which, according to WRB, identified the soil as Gleyic Fluvisol (Oxyaquic). It is identified as idesan series according to the local classification system (Moss,1957) because it is located at the lower slope and associated with impeded drainage and waterlogging, severally mottled with the water table at about 78 cm depth. The soil is gleying and moderately light-textured, the colour ranges from light yellowish-brown to dark greyish brown with mottles at the upper horizon of the profile and texture of the soil is sandy loam throughout the profile.

The soils in mapping unit D are classified as Udult on account of its udic moisture regime, presence of clay enriched horizon with low base saturation at a depth of 25cm below the upper boundary of the Bt horizon and the horizon having a CEC <16cmol/kg clay with the clay percentage steadily increase down the profile. The Bt horizons have ECEC/clay known as a kandic horizon, which is a diagnostic horizon dominated by low-activity clays (typically have clay texture), these classify the soil as Typic Kandiudult in USDA soil taxonomy. According to WRB classification, the soil qualifies as Haplic Acrisol (Nitic) base on the CEC of the soil is < 24 cmol/kg clay in the horizon within ≤ 50 cm and its base saturation is < 50% in the major part between 50 and 100 cm of the soil profile. It is identified in the local classification system (Moss, 1957) as Owode series because it is a medium textured, greyish coloured soils occurring at the middle slope of the landscape, a very workable soil with clay enriched subsoil, no gravel, plinthite or hardpan up to the depth of 181 cm, the soil is well-drained with a depth of water table below the profile depth. The colour ranges from dark greyish brown to strong brown with texture ranging from sandy loam to sandy clay throughout the profile.

The soils in mapping unit E have a slope of less than 25%, and the total thickness of human transported material in the surface horizons is less than 50cm, which classified it as Fluvaquentic Endoaquept in the USDA soil taxonomy. The gleyic properties throughout, reducing conditions in some parts of every sub-layer and the irregular decrease organic carbon with depth, identify the soil as Gleyic Fluvisol (oxyaquic) in the WRB classification. It is gleying and moderately light-textured soil located at the lower slope and associated with impeded drainage and waterlogging, severally mottled with the water table at about 60 cm depth, and the colour ranges from very dark brown to grey and the texture range from sandy loam to sandy clay throughout the profile, these classified the soil as Atan Series in the local classification system (Moss, 1957)

The soils in mapping unit F have more than 5% (by volume) plinthite in one or more horizons within 150 cm of the soil profile which characterize it as Plinthic Kandiudult according to soil taxonomy. It is identified as Pisoplinthic Acrisol (Vertic) in the WRB because the CEC of the soil is < 24 cmol kg-1 clay in the horizon within ≤ 50 cm and its base saturation is < 50% in the major part between 50 and 100 cm of the soil profile. The soil is identified as Pakoto Series in the local classification system (Moss, 1957) because it has a light textured surface soil with a mixture of pear-shaped iron-pan rubbles of boulder and gravel sizes at a depth of 60 cm but shallower as you move up the landscape and located at the upper and middle slope positions of the landscape, The soil is well-drained with a depth of table water below the profile depth.

The textural classes of the studied soils indicate remains of weatherable materials (sand, silt or clay) from the parent materials. The sand content decreases with depth in all the mapping units except for mapping unit E with irregular variation, sand was the dominant fraction, probably because the soils were derived from sedimentary rocks. The relative high sand content in the area is the reflection of the effect of the sandy parent material. The clay content increases irregularly with depth in all the mapping units except for mapping unit A, D and F. The relative higher clay content in the subsurface layer than in the surface may have resulted from the process of eluviation and illuviation (translocation of clay) from the upper horizon to the B horizon, which resulted in the formation of textural B horizons in the soils. The low clay content of the upper layer may further indicate the degree of leaching the soil has undergone, this is evident in Ultisols, formed by the process of clay mineral weathering, translocation of clays to accumulate in an argillic or kandic horizon and leaching of base-forming cations from the profile (Brady and Weil, 1999). Idoga and Azagaku (2005) noted that an increase in clay with depth might be the result of eluviation – illuviation processes as well as contributions of the underlying geology through weathering. According to Malgwi *et al*. (2000), lower clay content of the surface horizons could also be due to sorting of soil materials by biological and agricultural activities, clay migration or surface erosion by runoff or combination of these.

The soils of the studied sites are generally acidic with a pH range of 3.9- 6.4. The acid nature of the soils may be due to high-intensity rainfall in the area, which leaches basic cations down the profile and may be due to Al saturation of the exchange complex. Enwezor *et al*. (1981) stated that leaching of Ca and Mg are primarily responsible for acidity development in soils. Acidity (low pH) of the soils may also be due to the effect of cultivation, erosion and leaching of nutrients or a combination of these. Nevertheless, the exchangeable acidity values were low as their values were within the range of 0.4 to 5.6 cmol kg^{-1}. Such a range of values may not hinder crop production (Ukpong, 1995).

The low values of organic matter would encourage rapid leaching of cations into the subsoil from the surface. Also, the soils are low in ECEC (<9.16 cmol kg^{-1}), low in available P and total N. The phosphorus content of the soil is generally low based on the rating for Nigerian soils (<15 mg kg^{-1}) (Enwezor *et al.*, 1990; Adepetu, 2000), generally, the low phosphorus content may be due to high soil acidity which is not conducive for the release of P (Uzoho *et al*., 2004). It has been reported that in acid soils, P is fixed by acidic Fe, Al and Mn (Enwenzor *et al*., 1989).

The low CEC may be related to low organic matter content. Lal and Kang (1982) had observed that the higher the organic matter content of the soil, the higher the CEC. Lombin *et al.* (1991) also reported that organic matter content was a significant contributor to the CEC of the soil; therefore, the low CEC content of the soil could also likely be attributed to high rate of weathering of the parent materials. Brady and Weil (1999) pointed out that the cation exchange capacity (CEC) of most soils increases with pH; thus at shallow pH values, the CEC is also generally low. Exchangeable bases are generally low. There is low exchangeable Ca (<4.73 cmol kg^{-1}), low to medium exchangeable Mg (0.05 - 3.17 cmol kg^{-1}), and very low exchangeable Na (<0.27 cmol kg^{-1}) (Landon, 1991).

Mapping units A and F were grouped into capability subclass IIe with limitations of risk of erosion and low nutrient for both mapping units, and gravel content peculiar to mapping units F. This land class has a good potential for most arable crop production (e.g. maize, cassava, yam, etc.). Subclass e is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their use. Erosion susceptibility and past erosion damage are the dominant soil factors that affect soils in this subclass (USDA Natural Resources Conservation Service National Soil Survey Handbook). The risk of erosion may be due to slope of the land, runoff and sandy loose nature of the soils; a low nutrient is due to low CEC which indicate that the soil has a low potential for retaining plant nutrients and high gravel content in mapping unit F make the structure of the soil weak and make the soil very vulnerable to erosion in as much as they are easily detached under the impact of rain-drops or running water. When loose sand is deformed, there is a volume reduction due to sliding or rolling down into a compact state (Fasina *et al.,* 2015). Mapping units B and D were grouped into capability subclass IIs with limitation of the low nutrient reserve. Subclass s is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, stones, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content., the low nutrient is due to low CEC which indicate that the soil has a low potential for retaining plant nutrients and the sandy nature of the soil could result in low storage capacity of moisture and nutrients. At the same time, mapping units C and E were grouped into capability subclass IIIws with limitations of excess wetness and flooding hazard. Subclass w is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are the factors that affect soils in this subclass**;** subclass s is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, stones, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content. Soils with sandy loam texture at the surface have low infiltration rate, high water table and soils associated with impeded drainage and waterlogging are prone to excess wetness and flooding hazard.

Fertility capability classification is an objective evaluation of the limitations of the upper 50 cm of the soil to global arable crop production. Generally, the fertility status of the soils at the upper horizon is usually higher than the subsoil. The soil reaction ranges from strongly acidic to slightly acidic (pH range of 3.9- 6.4), organic carbon for mapping units A, B, C and F are lower than the critical level. Mapping A (Laek) are loamy, acidic and low nutrient reserve soils, which shows that the soils are well-drained (loamy strata types), not prone to flooding but have low fertility and acidity. Therefore the soils require less tillage practice, liming and application of fertilizer to increase the fertility status of the soil. One of the nutrients deficient in the soils is K. The nutrient is deficient probably because K is a soluble nutrient which can easily be leached by the excess water in the lowlands.

In contrast, the sandstones, which are the parent rock of the upland soils, are inherently low in K (Ojanuga, 2006). Mapping unit B (Sak) are sandy topsoil, acidity and low fertility, the sandy nature of the soil could result in low storage capacity of moisture and nutrients, soil acidity increases the Al toxicity because, at low pH, more soluble Al is being dissolved through leaching. According to Evans and Kamprath, (1970), about one-third of the tropics (1.5 billion hectares) have sufficiently strong soil acidity for soluble Al to be toxic to most crop species. This constraint is defined as having more than 60% Al saturation in some part of the top 50 cm of soil, and is found mainly in soils classified as Oxisols, Ultisols and closely related Inceptisols and is correlated with low nutrient capital reserves (Sanchez and Salinas, 1981). Therefore the soil requires more of organic manure to improve the water and nutrient storage capacity of the soil, application of fertilizer to increase the fertility and liming to increase the pH of the soil.

Mapping unit C (Saegk) are sandy topsoil, poorly drained, acidity and low fertility soils, the sandy nature of the soil could result in low storage capacity of moisture and nutrients, and the aquic condition of the soil could restrict cropping to the seasons of the year when there is less moisture from precipitation. Therefore the soil requires tillage practice, drainage, application of organic manure to improve the water and nutrient holding capacity of the soil, application of fertilizer to increase the fertility and liming to increase the pH of the soil.

Mapping unit D (Lr^+) are loamy topsoil with high gravel contents, which shows that the soils are well-drained (loamy strata types), not prone to flooding with no fertility limitation. Therefore the soils require tillage practice and suitable for arable crop production without soil amendment. Mapping units E ($Lagkr^+$) are loamy, gravelly, poorly drained, acidic and low nutrient reserve soils, which shows that the soils are well-drained (loamy strata types), not prone to flooding but have high gravel content, low fertility and acidic, The nutrient deficient in the soils is k, which is a soluble nutrient which can easily be leached by the excess water in the lowlands. In contrast, the sandstones, which are the parent rock of the upland soils, is inherently low in K (Ojanuga, 2006). Therefore the soils require less tillage practice, drainage, liming and application of fertilizer to increase the fertility status of the soil. Mapping unit F ($LRkr^{++}$) are loamy topsoil with root restricting layer and low fertility, though has loamy topsoil, but is highly rocky with unfavourable surface gravel concentration is non-arable and may be considered for other uses such as the building of farmhouses, cattle ranch or other farm infrastructures. It could also be developed for recreation purposes.

5.0. Conclusions

A total of about 77.68% of the soils are strongly leached, acid soils with relatively low native fertility; much of the basic cations have been leached from these soils due to intense weathering, and the subsurface horizon has an accumulation of clays while 22.32% of the soils are Inceptisols formed from alluvial materials. Some of the soils are associated with impeded drainage and waterlogging. The soils are generally strongly acidic to slightly acidic with a pH range of 3.9- 6.4. Pakoto Series though has loamy topsoil, but is very sloppy with unfavourable surface gravel concentration and is therefore adjudged non-arable. This unit may be considered for other uses. Application of fertilizer and drainage practices would be encouraged for healthy performance of many arable and vegetable crops in this area.

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