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Characterization and classification of soils of a toposequence at Osun sacred grove, Nigeria

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ABSTRACT

Rational use of forest resources without accurate knowledge of land and soil properties is a primary concern in achieving any millennium goal on afforestation. Hence, the morphological, physical and chemical properties of soils of a toposequence over coarse-grained granite gneiss at Osun sacred grove, in Osun State, south-Western Nigeria were studied. Three profile pits were dug under each landuse types (Teak and Gmelina plantations), making six pits in the location. Most of the pedons clearly expressed Argillic Bt horizon. Soil texture ranged from sandy loam to sandy clay loam. Soil structures ranged between medium sub-angular blocky and single grained. Bulk density values ranged from 1.31 to 1.69 gcm^{-3} and soils under teak plantation are generally higher in coarser texture with high gravel contents. The soils are slightly acidic. The soils had high base saturation, low CEC, and clay content increases with depth, regular decrease in organic carbon with an increase in depth is also observed. The soils are classified according to the United State Department of Agriculture (USDA, 2014) Soil Taxonomy and Food and Agriculture Organization- World Reference Base (FAO – WRB, 2014) as Alfisols and Inceptisol and having Udic moisture regime, under teak plantation, pedon 1, 2 and 3 were classified as Typic Kandiudalfs (Lixisols) , Lithic Dystrudepts (Leptosols) andPlinthaquic Kandiudalfs while under Gmelina plantation pedon 4,5 were classified as Typic Hapludalfs (Lixisols), and 6 as Aquic Kandiudalfs (Gleyic Lixisols). At the soil series level pedon 1,4 and 5 were classified as Iwo series, pedon 2 as Ekiti series, pedon 3 as Apomu series while pedon 6 was classified as Oba series.

1. Introduction

Soils on a long and sloppy landscape frequently occur in a well-defined and relatively regular sequence called toposequence. Soils occurring on a toposequence vary or differ in properties morphologically, physically and chemically. Consequently, the potentials of such soils for crop or tree production also differ from the summit to the lower slope segments.

Characterization of soil morphological, physical and chemical properties helps in delineation and management of soils. The physical and chemical properties of a soil are determined by the soil forming processes under which they form though all soils are created by the various development processes including additions, transformations, translocations, and removals. Soil surveys provide accurately scientific inventory of the soils occurring within a specified land area and involve the systematic examination, description, classification, and mapping of such soils. According to Esu (2010), during a soil survey, sufficient information is gathered in order to help the surveyor to correlate and to predict the adaptability of soils to various crops or trees, behaviour and productivity under different management systems. Soil characterization provides useful information for assessment and monitoring the behavior of soils (Alabi *et al*., 2017). Soils of Osun grove have been there for several years without knowing the physical and chemical properties of the soil. According to Esu (2004), the lack of information on the soil resources of any region contributes to the problem of soil degradation due to wrong uses and poor management of land resources especially forest resources. This study was therefore carried out to obtain detail characterization of the morphological, physical and chemical characteristics of Osun sacred grove, to give a taxonomic classification of the soils using the criteria of USDA (2014) and FAO/UNESCO (2014).

2.0 Materials and methods

2.1 The Study Area

The study site is shown in figure 1. Osun Sacred Grove is located along the banks of Osun River in Osogbo Local Government Area of Osun State, South Western Nigeria. Osun Sacred Grove is located approximately between latitudes 7˚44'50.0" - 7˚46'00.0" N and longitudes 4˚32'40"-4˚33'40" E. The grove covers an area of 75 hectares, and it is a typical example of actual primary rainforest that is fast disappearing in the West African Sub-region and one of the few vestiges of the rainforests in Nigeria. The micro climate within the grove is less humid than it is in a greater part of Southern Nigeria. The average rainfall is between 1250 mm and 1450 mm per annum. The temperature in this area is almost uniform throughout the year with minimal deviations from the mean annual temperature of 27^0C. February and March are the hottest months with a mean temperature of 29^0C and 28^0C respectively. The relative humidity of the area is between 92-99%. The mean annual total sunshine hour is about 7 hours with mean daily sunshine of about 8.5 hours. The exposure of Pre-Cambrian rocks, member of the basement Complex, from which the relatively fertile clay-loam of the grove is derived, was reported by Obaje, (2009) and Imeokparia (2000). An inventory of the rock types of Osun Osogbo grove reveals that two types occur. These are the coarse-grained Granite gneiss and Granite pegmatite rocks (Olajire, 2000). The vegetation of the site consists of primary vegetation. The vegetative cover include local and exotic woody species which include: *Chlorophora excelsa* (Iroko), *Terminalia superba* (Afara), *Terminalia glaucescens* (Idi), *Annona Senegalensis* (Ibobo), *Anogysus leocarpus* (Ayin), Teak (*Tectona grandis (gedu)*), (*Gmelina arborea* (Gmelina), Nigeria walnut etc.

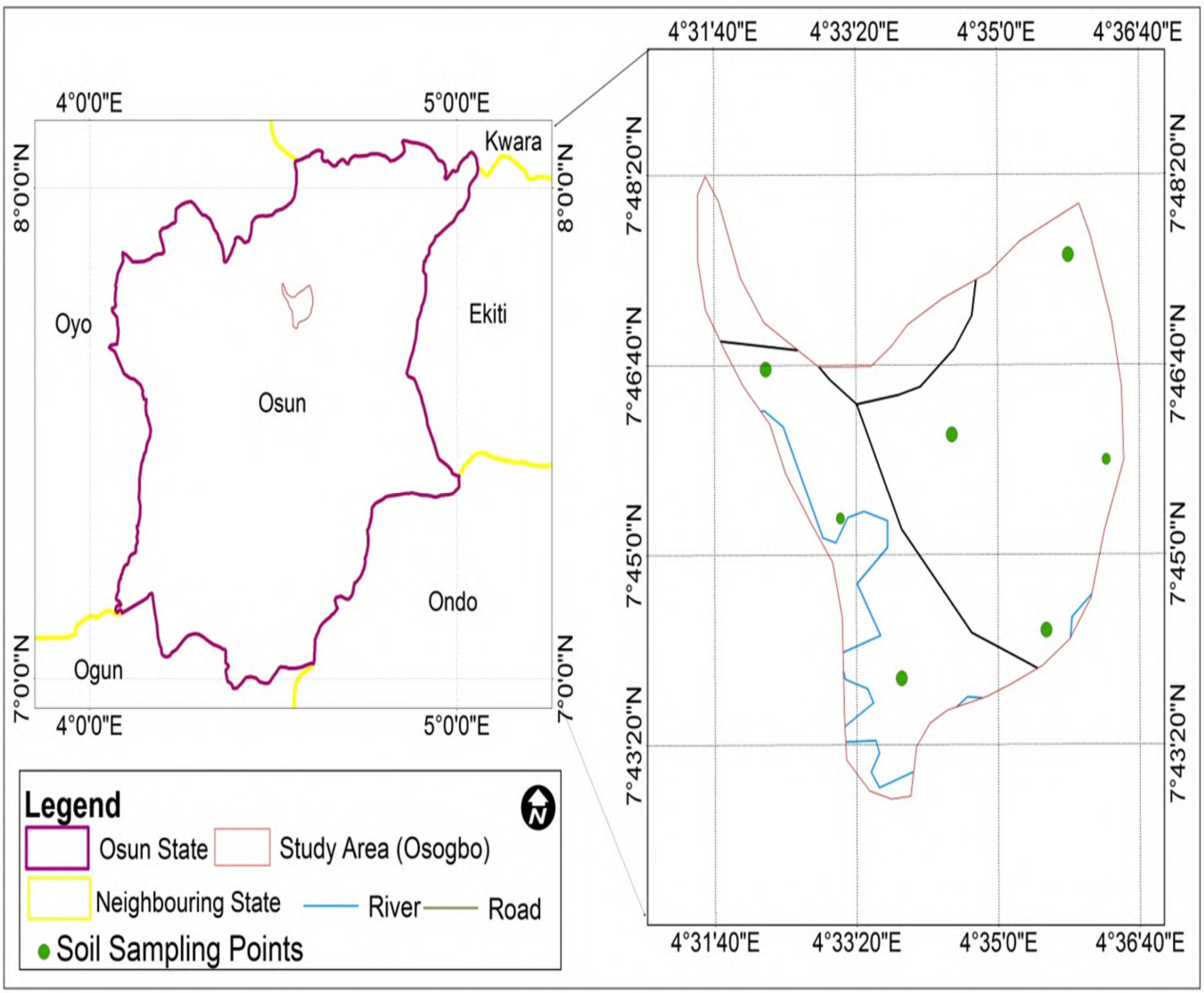

Figure 1: Location Map of Osun Sacred Grove

2.2 Field Studies

The area was sampled using the rigid-grid survey to cover the forest reserves. Three profile pits were dug on each land use type (Teak and Gmelina plantation) totaling six profiles in the location. The profiles were described using the guidelines of FAO/WRB (2014). A sampling of each profile was carried out according to the pedogenic horizons. After the profile description, bulk soil samples were collected using core sampler from identified genetic horizons for laboratory analyses. The digital elevation model of the study area was produced using Shuttle Radar Topographic Mapper at 90-meter resolution using ArcGIS 10.2 software. Furthermore, the digital terrain of the study area was also produced in order to delineate the area that are upper, middle, and lower slope, which will help to determine the topography of the study areas.

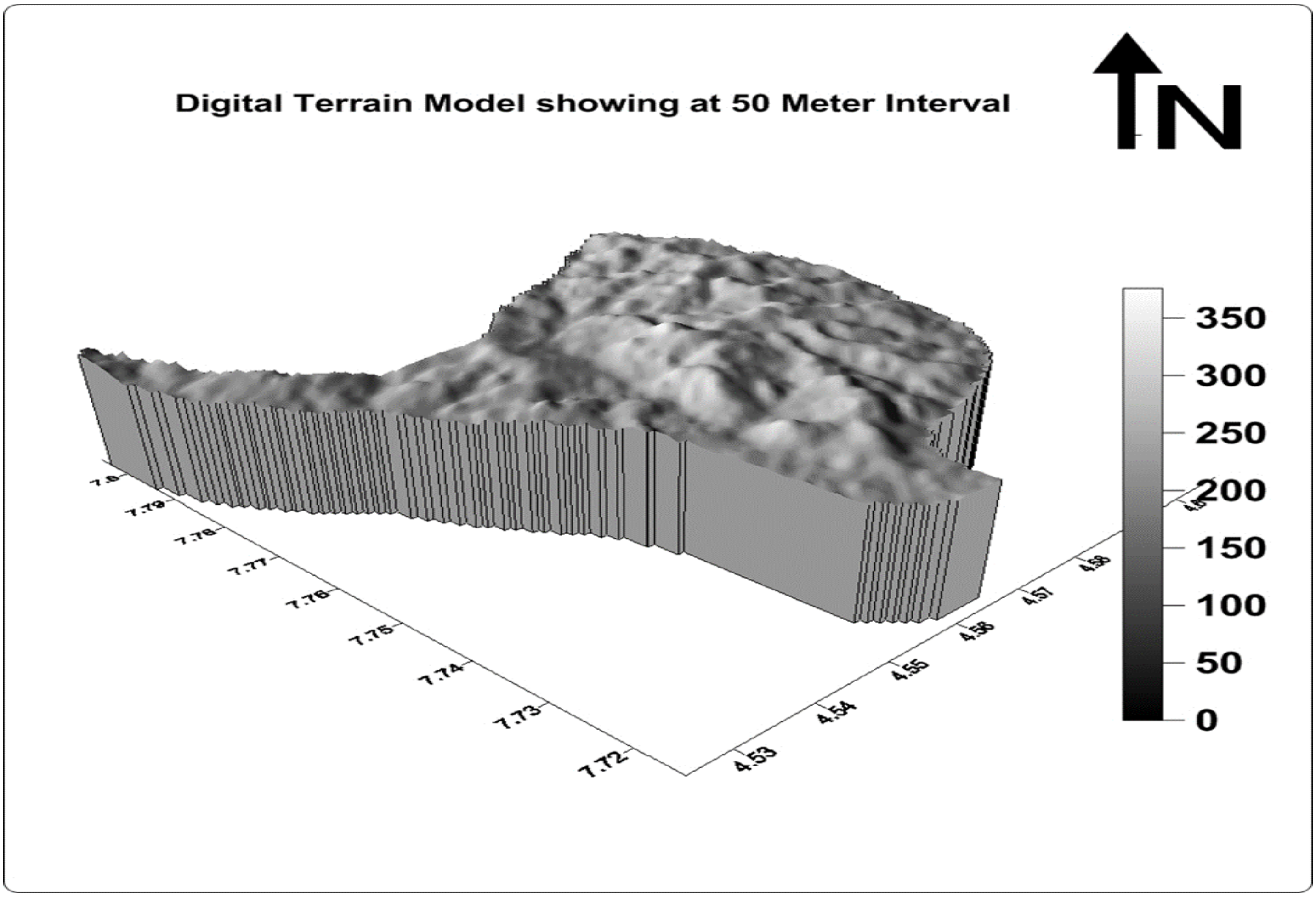

Figure 2: Osun sacred grove Digital Terrain model

2.3 Laboratory analyses

Collected soil samples were air-dried under room temperature (25 -28^{o} C). After air drying, some physical properties were carried out and subsequently sieved using 2 mm sieve, and the sieved soil samples were used for the laboratory determination of the soil properties.
Particle size analysis was determined using the hydrometer method (Bouyoucos, 1962, modified by Gee and Bauder, 1986 and 2002)
Soil pH was determined electrometrically in 1:1 soil-water suspension (IITA, 1982). Total soil organic carbon was determined using acid dichromate wet-oxidation procedure of Walkley and Black method (1934). Total Nitrogen was determined using the Kjeldahl digestion method. Exchangeable Ca, Mg, Na, and K was extracted with 1M ammonium acetate (1M NH4OAc) solution buffered at pH 7.0, as described by Anderson and Ingram (1998).The exchangeable sodium (Na^{+}) and potassium (K^{+}) content of the filtrates were determined by Flame photometer while the exchangeable calcium (Ca^{+}) magnesium (Mg^{+}) were determined by EDTA titration method and were read with atomic absorption spectrophotometer (AAS). Cation exchange capacity of the soil was determined with 1M NH4OAc (1M ammonium acetate), buttered at pH 7.0 (Chapman, 1965; Rhodes, 1982). The Effective Cation Exchange Capacity (ECEC) was obtained by the summation of exchangeable bases and exchange acidity. Organic carbon was determined by the wet oxidation method of Walkley-Black. The total nitrogen content of the soil was determined using the microKjeldahl technique as described by Bremner (1982). Available phosphorus was extracted using the Bray No.1 method (Mehlich 1984). The Bulk density was determined using the core method (Anderson and Ingram, 1993). Saturated hydraulic con-

ductivity (Ks) was estimated by the constant head soil core method as described by Reynolds (1993), The total porosity of the soils was estimated from the bulk density (BD) of the soil by assuming that the particle density (PD) of the soil was 2.65 $gcm^{-3.}$ Aggregate size distribution and stability were determined using the wet-sieving method (Kemper and Rosenau, 1986). The electrical conductivity of the soil was taken using a standard electrical conductivity meter.

3.0 Results and Discussion

3.1 Soil Morphological Properties

3.1.1 Morphological properties of Soils under Teak *(Tectona grandis* Linn. f) plantation at Osun Sacred Grove

In the upper slope of the teak plantation (*Tectona grandis*), the horizon of the profile had colour that ranged between Dark yellowish brown (10YR ¾) in the surface and yellow (10YR 7/8) in the subsurface horizon (Table 1). There was no mottling through the profile, indicating that the soils were well drained and well deep. However, the surface soils which were yellowish brown gradual increased in yellowness with an increase in soil depth become yellow at the last horizon. This observed change could have been caused by drainage or changes in the iron oxide chemistry of the soil (increase/decrease in the ratio of Fe^{2+}/Fe^{3+}). This profile had a sandy loam epipedon overlying sandy clay loam to sandy clay subsoils. The pedon had medium sub-angular blocky structure throughout the pedon.

The second pedon also under teak plantation at Osun sacred grove was located on the middle slope of the toposequence. The two horizons were identified here due to the presence of rock at depth 85 cm. The profile had different colour ranging from dark brown (7.5 YR 4/4) on the surface to Yellow (10 YR 7/8) in the subsurface. The profile had sandy loam texture throughout the pedon. The soil was not deep but well -drained because the rock was encountered at depth 85 cm. The pedon had medium sub-angular blocky structure throughout up to 85 cm depth. The area was surrounded by many rock outcrops.

Concretions, mottles were also absent throughout the pedon. The third pedon, under teak plantation, was located in the lower slope of the toposequence. The surface horizon of this pedon was dark brown (7.5 YR 4/2) while the subsurface horizon was Yellowish brown (10 YR 5/6). This pedon has sandy loam texture on the surface to sandy clay loam in the subsoils. The soil was deep and imperfectly drained with permanent water saturation at a depth of 175 cm as at the time of sampling and sampling was done during the dry season (Month of December). Black (7.5 YR 2/0), fine, coarse, distinct, prominent mottles were encountered between 36 cm to 175 cm depth. Iron- manganese concretions were identified in the subsurface horizon between depths 36 cm and 175 cm. With an increase in depth, the mottles and concretions became many, coarse and prominent. The pedon had a structure that ranged between single grained in the surface to fine subangular blocky in the subsurface soils.

3.1.2 The morphological properties of Pedons under Gmelina (*Gmelina arborea*) plantation at Osun Sacred Grove

The first profile was also located in the upper slope of the toposequence.
The pedon has colour variation ranging from dark yellowish brown (10 YR ¾) on the surface soil to reddish brown (5YR4/4) and Yellowish brown (10 YR 5/6). The profile had sandy loam texture on the surface soil overlying sandy clay loam subsoils. The pedon had medium sub-angular blocky structure throughout the pedon. The mottles which were dark yellowish brown (10 YR 3/2) were common in abundance, medium in size and distinct in contrast, were observed in the third horizon of this upper slope at depth 83-147 cm. The second pedon was located in the middle slope of the toposequence under Gmelina (*Gmelina arborea*) plantation. The soil colours were reddish brown (5YR 4/3), reddish brown (5YR4/4) and strong brown (7.5YR 5/6) respectively. The reddish colour of the soils is indicative that these soils are highly weathered and the dominance of iron oxides in the pedogenic environment. There was no evidence of mottles and concretions throughout the pedon. The pedon had medium subangular blocky structure.

The third profile was located at the lowest elevation in the toposequence also under Gmelina plantation. It is characterized by a uniform sandy clay loam to sandy loam in the subsoils. The colour variations ranged from dark yellowish brown (10YR 4/4) to strong brown (7.5YR 5/6) and Yellowish brown (10 YR 5/6) in the subsoils. The soil had a structure that varied from medium sub-angular blocky in the surface soil to fine, thin crumb structure in the subsurface. There was no evidence of mottles and concretions throughout the profile.

3.2 Soil Physical Properties

3.2.1The physical properties of soils under teak (*Tectona grandis*) plantation at Osun Sacred Grove

Profile pits, except the middle slope profile, were well deep (210 cm and 175 cm depth) respectively. The middle slope profile reached 85 cm when parent material was encountered. This is an indication of young soils. The well deep of upper and lower slope profile is an indication of well-developed soils (Jim 2003, Salako *et al*; 2006). The textural class of the soils ranged from sandy loam to sandy clay loam which is an indication of agriculturally desirable soil types (Salako *et a*l., 2006). The silt content decreases down the profile in the upper and the middle slope profile except for lower slope, which increases down the profile. The sand and clay content fluctuate down the profiles. There was translocation of clay in the second horizons of the upper and lower slope profiles, which is an indication of Argillic B horizon (Bt). The gravel content of the upper slope profile was high and erratic down the profile with values ranging from 38.05 - 50%, while that of middle slope decreased down the slope (38.30 - 33.35%) and that of the lower slope increased down the slope (10.95 - 27.75%). This high gravel content indicates that total pore space is reduced and plants are more likely to be susceptible to the effects of drought and water logging (McKenzie *et al*; 2002).

Table 1: Morphological characteristics of the Pedons under Teak plantation at Osun Sacred Grove

SS/Topo.	Horizon Designa-tion	Horizon Depth (cm)	Soil Tex-ture	Soil Struc-ture	Consis-tence	Soil Colour (Moist)	Mottles	Concretion	Horizon Boundaries
Upper slope	A	0-30	SL	MSAB	Fr, s	Dark Yellowish brown (10YR ¾)	Absent	Absent	Gs
	Bt	30-145	SCL	CSAB	Vfi,	Strong brown (7.5YR 5/6	Absent	Absent	Gs
	B2	145-210	SL	MSAB	Fi, st	Yellow (10YR 7/8)	Absent	Absent	-
Middle slope	A	0-53	SL	MSAB	Fi	Dark brown (7.5YR 4/4)	Absent	Absent	Cw
	Cr	53-85	SL	MSAB	Fr, l	Yellow (10YR 7/8)	Absent	Absent	-
Lower slope	A	0-36	SL	SG	Fr, l	Dark brown (7.5YR 4/2)	7.5 YR 2/1 c,f, d,	Fe-Mn, (2.5 YR 4/8)	Gs
	Bt	36-175	SCL	FSAB	Fi.shd	Yellowish brown (10 YR 5/6)	7.5 YR 2/0 m,cr,p	Fe-Mn,	-

SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam, FSAB = Fine sub angular blocky; MSAB = Medium sub angular blocky; CSAB= coarse sub angular blocky, +Fr = friable; Fm = Firm; shd = Slightly hard, s = soft, c=common, f=fine, d=distinct,s=sharp, m=many, cr=coarse, p=prominent, gs= gradual smooth, gw= gradual wavy, cs= clear smooth

Table 2: Morphological characteristics of the Pedons under Gmelina plantation at Osun Sacred Grove

SS/Topo	HD	HDp (cm)	Soil T	Soil S	Consistency	Soil C (Moist)	Mottles	Concretion	HB
Upper Slope	A	0-26	SL	MSAB	Fr, ss,	Dark yellowish brown(10 YR 3/4)	Absent	Absent	gs
	Bt1	26-83	SCL	MSAB	Vfi, shd	Reddish brown (5YR 4/4)	Absent	Absent	cw
	Btc	83-147	SCL	MSAB	Vfi, vs	Reddish brown (5 YR 4/4)	10YR 3/2 c, m, d	Fe-Mn	cw
	B3	147-210	SCL	MSAB	Vfi, vs	Yellowish brown (10YR 5/6)	Absent	Absent	--
Middle Slope	A	0-28	SCL	MSAB	Fi, s	Reddish brown (5YR4/3)	Absent	Absent	gs
	B1	28-72	SC	MSAB	Fi, vs	Reddish brown (5YR4/4	Absent	Absent	cw
	B2	72-206	SL	MSAB	Vfi, ss	Strong brown (7.5YR5/6)	Absent	Absent	---
Lower Slope	A	0-41	SCL	MSAB	Fi, shd	Dark yellowish brown (10YR4/4)	Absent	Absent	gs
	B1	41-137	SCL	MSAB	Vfi, hd	Strong brown (7.5YR5/6)	Absent	Absent	gs
	B2	137-188	SL	CSAB	L	Yellowish brown(10YR5/6)	Absent	Absent	-

SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam ‡ FSAB = Fine sub angular blocky; MSAB = Medium sub angular blocky; CSAB= coarse sub angular blocky, Fi= fine, Vfi=Very fine, c= common, m=medium, d= distinct + Fr = friable; Fm = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft, HD =Horizon designation, HDp =Horizon Depth, SC= Soil Colour, SS= Soil structure, HB= Horizon Boundary, Conc = Concretion, ST = Soil Texture

A distinctive characteristics feature of the soils was high sand, high to moderate clay, high moderate silt and high to moderate gravel contents. The sand content of the soil ranged from 590-810 g/kg, the silt ranged from 48-168 g/kg while the clay content ranged from 162-362 g/kg. The sand particle content of the soils fluctuate in all profile with increase in soil depth whereas the clay content increase with an increase in depth which shows the evidence of argilluviation (Bt) horizons in the upper soil profile, but there was no evidence of argilluviation in the middle and the lower slope profiles despite the increased clay content with an increase in depth. This increase in clay content down the profile depth may be attributed to eluviations process and an indication of old weathered soils. Apart from lower slope were silt content of the soil decrease with depth, there was no consistent pattern in the silt-size particles in the other profiles. The soil texture ranged from sandy loam to sandy clay loam and sandy clay in the subsurface horizons. The gravel content increased with increase in profile depth. This is an indication that the soil is loose and porous. The gravel content ranged from 585 to 6505 g/kg. The bulk density of these soils ranged from 1.39 to 1.82 g/cm^3. The increase in bulk density as the profile depth increased in the upper slope could be caused by translocation of clay content from the overlying horizon (1.51 – 1.77 g/cm^3). However, the bulk density decreases with increased profile depth in the other profiles and not exceeding 1.82 g/cm^3 which suggest that it may not offer mechanical impedance to root penetration.

The soil total porosity ranged between 26.32 and 86.45% and generally increased with an increase in profile depth. The surface soils have poor porosity values (27.37, 37.53, 27.31%) respectively and classified as poor soils and the subsurface soil have good porosity value because Kachinkil (1965) suggested over 50% for good soils, between 45 to 50% satisfactory soils, while 40 to 45% unsatisfactory soils, under 40% and below for poor soils. This could be attributed to high sand content in the surface soils which contain mostly macro pores that generally cannot retain water against gravity and are usually filled with air and good porosity of sub soils could be attributed to high clay content with micro pores that are small enough to retain water against gravity.

Table 3: Physical properties of pedons under Teak plantation at Osun Sacred Grove

Pedon	Horizon Depth	Horizon designa-	Sand g/Kg	Silt g/Kg	Clay g/Kg	Textural class	Gravel (g/kg)	Bulk density	Ksat cm^3/hr	Total porosity	Clay Disp.	EC (dS/m)
Upper slope	0-30	A	770	108	122	SL	4690	1.36	1.47	30.71	4.66	1
	30 -145	Bt	630	48	322	SCL	4995	1.34	0.50	113.18	5.79	1
	145 -210	B2	810	48	142	SL	3805	1.45	1.18	33.18	6.87	1
Middle slope	0-53	A	750	128	122	SL	3830	1.50	1.08	22.60	4.61	1
	53-85	Cr	830	28	142	SL	3335	1.67	0.85	23.67	5.32	0.7
Lower slope	0-36	A	830	8	162	SL	1095	1.31	1.14	43.85	6.43	1
	36-175	Bt	770	28	202	SCL	2775	1.47	0.99	68.41	4.50	1

Table 4: Physical properties of pedons under Gmelina plantation at Osun Sacred Grove

Pedon	Horizon Depth (cm)	Horizon designa-tion	Sand g/kg	Silt g/kg	Clay g/kg	Tex-tural class	Gravel (g/kg)	Bulk density g/cm^3	Ksat cm^3/hr	Total poros-ity (%)	Clay Disp. Ratio	EC (dS/m)
Upper slope	0-26	A	810	58	132	SL	585	1.51	1.15	27.37	6.09	4
	26-83	Bt1	590	88	322	SCL	2200	1.65	0.39	86.45	4.43	1.3
	83 -147	Btc	650	48	302	SCL	6505	1.69	0.41	82.48	4.71	2
	147-210	B3	750	88	162	SL	2800	1.77	0.85	32.87	6.51	1
Middle slope	0-28	A	690	68	242	SCL	3680	1.55	0.34	37.53	5.10	1
	28-72	Bt	590	48	362	SC	5530	1.55	0.20	59.82	8.86	1
	72-206	B2	670	168	162	SL	5200	1.54	0.67	26.32	6.43	1
Lower slope	0-41	A	690	108	202	SCL	3380	1.82	0.41	27.31	4.06	1
	41-137	Bt	650	48	302	SCL	2815	1.39	0.21	40.64	6.35	1
	137-188	B2	790	48	162	SL	4180	1.56	1.12	43.70	5.32	1

Ksat= Hydraulic conductivity, EC= Electrical conductivity

3.3 Soil Chemical Properties

3.3.1 The chemical properties of pedons under Teak (*Tectona grandis Linn. f*) plantation at Osun Sacred Grove.

The soil reaction (pH) in water (1:1) ranges from moderately acid to slightly alkaline (6.0 - 7.8). The total nitrogen of the soil ranges from very low to low (0.06 – 0.12%). Total nitrogen levels between 0.1 and 0.2 % are considered to be low, while below 0.1% is regarded as very low (Landon, 1984). One of the basic features of the tropical environment is its high temperature which leads to rapid loss of soil nitrogen due to volatilization (Olowolafe and Dung, 2000). Heavy rainfall events leading to leaching also contributed to nitrogen losses in this environment. The organic carbon ranges from low to moderate (0.5 – 1.12%). The percent organic matter ranges from low to medium (0.86 – 2.02%) due to accumulation or deposition of leaf litter that is partially decomposed (i.e. intermediate decomposition) on the surface soils.

The soils available phosphorus ranged from low to medium. It was rated low in the subsoil horizons but medium in the surface horizons. The values ranged from 5.27 to 12.44 mg kg-1. The generally low to medium available P in this soil is evident from moderately acid to slightly alkaline nature of the soils because P fixation has been reported as one of the unique properties of acid tropical soils (Kamprath, 1984). An increase in available P in the observed second horizon of upper slope profile could be explained based on Anderson and Xia (2001) that some solute P from the surface horizon can travel rapidly through horizons of low P status to greater depth in the soil by preferential flow, actually, preferential flow might have effect on inconsistent clay behaviours down the profile depth, (clay content increased from 122 – 322 g kg-1).

The exchangeable calcium (Ca) ranged from 1.18 to 2.78cmol/kg. The values in the top soils ranged between 2.40 and 2.64cmol/kg while the subsurface values were from 1.18 to 2.78cmol/kg. The exchangeable potassium (K^+) ranged from high to moderate. The values ranged from 0.27 to 0.43cmol/kg. The top soil values ranged from 0.37 to 0.41cmol/kg while the subsurface soil varied from 0.27 to 0.43cmol/kg. The exchangeable Magnesium (Mg^{2+}) varied from 1.37 to 2.86 Cmol/kg. These values were considered moderate for the soil. The variation of the values at the surface soils was from 1.39 to 2.16 Cmol/kg while the subsurface ranged from 1.37 to 2.86 Cmol/kg.

On the other hand, exchangeable sodium (Na^+) varied from 0.22 to 0.49 Cmol/kg. The topsoil value ranged from 0.44 to 0.49 Cmol/kg while that of subsoil varied from 0.22 to 0.41 Cmol/kg. The CEC of the soil is generally regarded as low. Values ranged from 3.45 to 6.68 Cmol/kg. The low CEC values from all the pedons reflect the meager soil organic carbon and clay of kaolinitic type according to Jim, 2003. From the obtained, it was observed that the percent based saturation from all pedons were high (>50%). This does not mean that the soils have high basic cations but because the kaolinitic clay content as the low capacity to adsorb cations

Table 5: Chemical properties of Pedons under Teak plantation at Osun Sacred Grove

Pedon	Horizon Depth (cm)	Horizon Designa-tion	pH (H_2O)	pH KCl	CEC Clay	OC %	OM %	N %	P (mg/kg)	K^+ (cmol/Kg)	Ca^{2+} (cmol/Kg)	Mg^{2+} (cmol/Kg)	Na^+ (cmol/Kg)	Silica %	H+ (cmol/Kg)	ECEC (cmol/Kg)	B.S %
Upper slope	0-30	A	7.80	6.14	4.99	1.12	1.93	0.12	11.83	0.41	2.64	2.16	0.49	61.15	0.07	5.77	98.71
	30-145	Bt	6.80	5.32	5.28	1.09	2.02	0.13	12.44	0.43	2.78	2.86	0.51	57.63	0.10	6.68	98.18
	145-210	B2	6.20	4.33	2.32	0.50	0.86	0.06	5.27	0.81	1.18	1.75	0.22	61.15	0.12	3.45	94.63
Middle slope	0-53	A	6.00	5.25	4.56	1.02	1.74	0.11	10.73	0.37	2.40	1.96	0.44	55.87	0.09	5.26	97.95
	53-85	Cr	6.90	5.21	2.90	0.64	1.10	0.07	6.76	0.27	1.51	1.67	0.28	57.63	0.08	3.77	97.11
Lower slope	0-36	A	6.80	5.44	4.63	1.03	1.78	0.11	10.94	0.38	2.44	1.39	0.45	55.87	0.07	4.73	98.48
	36-175	Bt	6.60	5.29	4.21	0.94	1.16	0.10	9.90	0.34	2.21	1.37	0.41	51.47	0.08	4.41	98.09

and the little available bases will easily saturate the exchange site (Kparmwang *et al*; 1998).

3.3.2 The chemical properties of Pedons under Gmelina plantation at Osun Sacred Grove

The soil pH ranged from very strongly acid to Neutral (5.0 – 6.6). The soil total nitrogen ranged between very low to low with values ranged from 0.05 – 0.1% Landon, (1984) reported that total N levels between 0.1 and 0.2% are considered to be low.

The organic carbon of the soils was generally low, less than 2%, values ranged from 0.75 and 1.96%. The available phosphorus ranged from low to medium, it has a value ranged from 4.87 to 12.04 $mgKg^{-1}$ with the highest value in the second horizon of upper slope and the last horizon of the lower slope profiles i.e. 10.05 $mgkg^{-1}$ and 12.04 $mgkg^{-1}$ respectively. This could be explained as evident from very strong acid to neutral nature of the soils because it has been reported that P fixation is one of the unique properties of acid tropical soils (Kamprath, 1984).

The soils had exchangeable acidity (EA) ranged from 0.08 – 0.15 Cmol/kg. Similar to most tropical soil the exchange sites of the soil were dominated by moderate to high levels of exchangeable magnesium (Mg^{2+}) and sodium (Na^{+}). While the exchangeable magnesium of the soils ranged from 0.82 to 3.78 $Cmol/kg^{-1}$, the exchangeable sodium (Na^{+}) ranged between 0.20 and 0.49 Cmol kg^{-1}. Exchangeable potassium (K^{+}) was low and varied from 0.17 – 0.34 Cmol kg^{-1} while the exchangeable calcium (Ca^{2+}) varied from 1.08 – 2.69 Cmol kg^{-1}. The effective cation exchange capacity (ECEC) of the soils is low and ranged from 3.22 – 7.49 Cmol/kg and the base saturation of the soil was considered high and varied from 93.47 – 97.95%.

3.4 Soil Classification

Based on criteria of USDA, Soil Taxonomy (Soil Survey Staff, 2010, 2014), the pedons at the upper and lower slope under teak plantation and all pedons under Gmelina plantation clearly expressed Argillic (Bt) and Kandic horizons, Udic moisture regime, low CEC, the soils had base saturation greater than 50%, and clay content increases with depth, regular decrease in organic carbon with increase in depth is also observed. Therefore, the pedons were classified as order Alfisols while middle slope pedon under teak plantation exhibited cambic horizon, lithic contact, low CEC, high base saturation and was classified as an Inceptisol due to its skeletal nature. The soils were classified as Udalfs and Udepts based on the moisture regime at the suborder level.

Pedon 1 at the upper slope under Teak plantation has an Ochric epipedon, Argillic horizon (Bt) at depth 30-145, CEC (clay) value < 16 cmol/kg (12.59 cmol/kg), ECEC of 15.90 cmol/kg, high base saturation > 90 %, Udic Moisture regime. The pedon was classified as order Alfisols, with Udic moisture regime as Udalfs at sub-order level, it has no densic or lithic contact throughout the pedon, therefore clas-

Table 6: Chemical properties of Pedons under Gmelina plantation at Osun sacred grove

Pedon	Horizon Depth (cm)	Horizon Designation	pH (H_2O)	pH (Kcl)	CEC/ Clay (Cmol/Kg)	OC %	OM %	N %	P mg/kg	K^{+} (Cmol/Kg)	Ca^{2+} (Cmol/Kg)	Mg^{2+} (Cmol/Kg)	Na^{+} (Cmol/Kg)	Silica %	H+ (Cmol/Kg)	ECEC (Cmol/Kg)	B.S %
Upper slope	0-26	A	6.60	5.32	4.24	0.95	1.62	0.10	9.97	0.34	2.23	0.89	0.41	53.23	0.09	3.96	97.95
	26-83	Bt1	6.60	5.07	4.29	0.95	1.64	0.10	10.05	0.34	2.24	1.88	0.41	54.11	0.10	4.97	97.60
	83-147	Btc	6.00	5.40	3.87	0.86	1.48	0.09	9.10	0.31	2.03	2.59	0.38	51.47	0.08	5.39	97.76
	147-210	B3	6.60	5.28	3.69	0.82	1.41	0.09	8.63	0.30	1.93	2.81	0.36	60.27	0.09	5.49	97.53
Middle slope	0-28	A	6.00	4.45	3.52	0.77	1.33	0.08	8.13	0.28	1.82	0.82	0.34	62.03	0.13	3.39	96.23
	28-72	B1	6.00	4.28	3.26	0.71	1.23	0.07	7.52	0.26	1.68	1.32	0.31	55.87	0.13	3.70	94.45
	72-206	B2	5.60	4.30	2.98	0.65	1.11	0.07	6.81	0.24	1.52	3.13	0.28	61.15	0.14	5.31	95.14
Lower slope	0-41	A	5.80	4.19	3.10	0.67	1.16	0.07	7.10	0.24	1.59	1.38	0.29	54.11	0.15	3.65	94.02
	41-137	B1	5.00	4.30	2.17	0.46	0.75	0.05	4.87	0.17	1.08	1.63	0.20	64.67	0.14	3.22	93.47
	137-188	B2	5.90	5.40	5.12	1.14	1.96	0.12	12.04	0.42	2.69	3.78	0.49	62.91	0.11	7.49	97.38

CEC =Cation exchange capacity, OC= Organic carbon, OM= Organic matter, N= Nitrogen, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Na= Sodium, H= Acidity, ECEC= Effective cation exchange capacity, B.S %= percent base saturation sified as Kandiudalfs at great- group level and Typic Kandiudalfs at sub-group level while according to FAO/WRB (2014), it is classified as Lixisols.Sedentary soil, well deep, well-drained, no mottles, no concretions (Iwo series).

Profile 2 at the Middle slope under Teak plantation- shallow (has an Ochric A and C horizon), low CEC 7.46 Cmol/Kg, ECEC 9.03 cmol/kg, cambic horizon, Base saturation >98 %, High Fe and Mn, Therefore, belong to order Inceptisol, having Udic Moisture regime, classified as Udepts at suborder level and with lithic contact within 50 cm of the mineral soil surface classified as Dystrudepts at great-group level and Lithic Dystrudepts at sub-group level and as Leptosols (FAO/WRB, 2014). Sedentary soil, skeletal in nature, well-drained but not deep, large parent material encountered at depth 85 cm, surrounded with many rock outcrops, (Ekiti series). **Profile 3** at the lower slope, has Bt horizon at depth 36-175 cm, presence of an Ochric A horizon, CEC 8.84 cmol/kg, ECEC 9.14 cmol/kg, Base saturation >50%, therefore classified as Kandiudalfs at great-group level and having about 5% or more plinthite in horizons within 150 cm of the mineral soil surface accompanying by redox concentration and Aquic conditions for sometime in normal years, classified as Plinthaquic Kandiudalfs at sub-group level and as Dystric Plinthosol (FAO/WRB, 2014). Hill-wash soil, deep and imperfectly drained, (Apomu series)

Profile 4 is classified as order Alfisols, sub-order Udalf and placed in the great-group Hapludalfs and sub-group Typic Hapludalfs, Lixisols (FAO/WRB, 2014). Sedentary soil, well deep and well drained (Iwo series), **Profile 5** is classified as order Alfisols and sub-order Udalfs, Hapludalfs at the great-group level and Typic Hapludalfs at sub-group level, Lixisols (FAO/WRB, 2014) for the same reasons as pedon 4. **Profile 6** has Kandic horizon, low CEC, base saturation >50%, aquic moisture regime. Therefore classified as order Alfisols, sub-order Kandiudalfs, great-group aquic Kandiudalfs and Gleyic Lixisols (FAO/WRB, 2014). Hill-wash soil, fine colluvial material, no evidence of mottles and concretions throughout the profile (Oba series)

3.5 Conclusion and Recommendation

The part of the study area is a part of the coarse-grained granite - gneiss of Pre-Cambrian basement complex in south -western Nigeria which is characterized by very sandy soils. Particle size distribution indicates that water retention ability of all soils was low while the infiltration rate will be high. It is therefore imperative that appropriate soil management practices be adopted to ensure sustainable tree production. The Implication of variation in soil properties is that plantation of the same age occurring on different topographic positions would have to be managed differently. This study concluded that management practices of the plantations should be site-specific and cater for topographic variations.

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