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Pedogenesis and Classification of Soils along a Toposequence at Omo Forest Reserve in the South-West, Nigeria

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Abstract
Characterization of soil morphological, physical and chemical properties helps in delineation and management of soils. This necessitates establishing the characteristics of Omo Forest Reserve soils as well as their classification. The experimental site was delineated on a topographic map of Ijebu-East Local Government area of Ogun State and a rigid-grid method of soil survey was used to establish the mapping unit. The profiles pits were described using the guidelines of FAO (2006) and USDA Soil Survey manual and samples taken from identified horizons. Laboratory analysis was carried out to determine some physical properties like Bulk density (1.12 -1.57 g/cm^3), saturated hydraulic conductivity (0.53-2.79cm^3/hr), total porosity, electrical conductivity (1 -3 ds/m) and chemical properties as Particle size analysis was determined using the hydrometer method, Soil pH, soil organic carbon, total Nitrogen, available Phosphorus, Exchangeable Ca, Mg, Na and K were also determined. The result showed that the soils had high base saturation which ranges from 92.2- 98.64%, low CEC (3.15- 8.17cmol/kg), clay content increased with depth, regular decrease in organic carbon (1.47 – 0.43%) with increase in depth was also observed. Most of the Pedons clearly expressed Kandic horizon and Udic moisture regime. Therefore, all the pedons were classified as order Alfisols. The soils were classified as Udalfs based on the prevailing moisture regime at the suborder level and they all belong to Effon series.

Keywords: Pedogenesis; Forest reserve; Alfisol; Kandic horizon; Udalfs; Effon series

Introduction
Soil is a major natural resource developed as a result of the interaction of the environmental factors of landform, climate, biological processes, including the activities of man, vegetation, micro and macro-organisms with the underlying geology over time (Dokucheauv, 1949). In a natural landscape, the kind of soil in a given location depends on the environmental factors of soil formation (Aruleba, 2011).

Pedogenesis is a process of soil development which was principally controlled by climate and vegetation (Dokuchaev, 1949). Plantation trees bring about changes in edaphic, microclimatic, flora, fauna and other components of the eco-systems through biocycling of mineral elements and environmental modification (Shukla, 2009). Soil quality embraces assessment of soil properties and processes relating to capacity of soil to function effectively as a component of a healthy ecosystem (Schoenholtz *et al.*, 2000). Soil properties result from the action and interaction of soil forming processes also known as pedogenic processes. The type and intensity of these pedogenic processes are often governed by environmental factors (climate, topography, vegetation etc.), as influenced by anthropogenic or human activities.

The role of forest in natural ecological systems, had led to increase and keen interest in its natural environment. This is attributed to the enormous advantages of the forest with respect to environmental conservation, protection, economic and social benefits. Forest generally contributes to the stabilization of soil, conservation and cycling of nutrients, as well as moderation of water supplies, especially in a world currently threatened with climate change and global warming (World Bank, 1992).

Sustainable land management requires a basic understanding of the nature and properties of soils.

This could be achieved by detailed soil description and classification. Soil classification, particularly at series level has been reported to be useful as basis for yield prediction (Fasina *et al.*, 2007) though the management of the land must be specified.

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. Pedogenesis is the transformation of the soil parent materials and the interaction of soil forming factors over a period of time in a synergistic process that results to a soil matrix.

Pedogenic studies would provide information on the properties (spatial and temporal) and nature of soils of an areas and how these properties influences or are influenced by the disparities in their positions on a landscape. It will also make available information on the land resource characteristic of the area, upon which conclusions can be drawn on the most appropriate land use to ensure sustained productivity. Characterizing the soil under planted forest will provide basic information for better management of the soil resources and equip our resource farmers on how best to improve on their productivity and ensuring environmental sustainability. Thus, the objectives of this study were to examine the morphological, physical and chemical properties of the soil along a toposequence in Omo forest reserves and to classify these soils.

Materials and Methods

Description of the site

The study was conducted in Omo forest reserve, Area J4 in the South-Western part of Nigeria, about 135 km North-East of Lagos and 80 km East of Ijebu-Ode. The reserve covers an area of about 130,500 hectares (strict nature reserve and artificial plantation) and the experimental land space covered about 7.5 hectares (artificial plantation) and lies between latitude 6'35^0 and 7'05^{0}N and longitude 4'05^0 and 4'40^{0}E.

Geologically the Reserve lies on crystalline rocks of the undifferentiated basement complex which in the southern parts is overlain by Eocene deposits of sand, clay and gravel. The terrain is undulating and the maximum elevation of 150 m above sea level is towards the west while the lowest parts of the Reserve are in the South where the River Omo joins River Oni before flowing into the Lekki Peninsular on the Atlantic coast. The Lagos-Ore-Benin Highway passes through the Southern tip of the Reserve. The reserve lies within the Equatorial belt and has a mean annual rainfall range of 1,200 to 1,600 mm per year. November or part thereof is often times dry along with December and January each year. Sometimes, double maximal of rainfall is experienced while a dry period would exist between July and August commonly referred to as August break.

Temperatures are high in the dry season when up to 33^{0}C could be recorded. The temperature is lower in the rainy season and ranges between 21^{0}C and 28^{0}C. The reserve naturally is dominated by high forest species. Most of the natural forests had been logged in the past and the species include*: Entandrophragma cylindricum; Khaya grandifoliola; Afromosia elata; Triplochiton scleroxylon; Nauclea diderichii; Milettia excelsa; Terminalia superba; Terminalia ivorensis* and hosts of other rain forest species (Augustine, 1995).

Field Studies

The area used was delineated on a topographic map of Ijebu-East Local Government area of Ogun State. The experimental sites were selected to cut across major soil series of Smyth and Montgomery (1962) along a toposequence, using soil and site descriptions from 0-100 cm auger samples to establish the mapping unit. Six mapping units were established with three on each land use type and six soil profiles were dug to represent the Six mapping units, i e three profile on each land use type (Teak and Gmelina plantation). The profiles were described using the guidelines of FAO (2006) and USDA Soil Survey manual (Soil survey staff, 2014) Sampling of each profile was carried out according to the pedogenic horizons. The digital elevation model of the study areas were 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.

Laboratory Analyses

Collected soil samples were air dried under room temperature. After air drying, some physical

properties were carried out and subsequently sieved using 2 mm sieve and 0.5 mm sieve (for organic carbon and Nitrogen determination). 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 Or, 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). The total Nitrogen content of the soil was determined using the micro-Kjeldahl technique as described by Bremner (1982). Exchangeable Ca, Mg, Na and K were 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 (Rhoades, 1982). The Effective Cation Exchange Capacity (ECEC) was obtained by the summation of the values of exchangeable bases and exchange acidity. Available phosphorus was extracted using the Bray No.1 method (Bray and Kurtz, 1945). The Bulk density was determined using the core method (Anderson and Ingram, 1993). Saturated hydraulic conductivity (Ks) was estimated by the constant head soil core method as described by Reynolds (2002). 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.

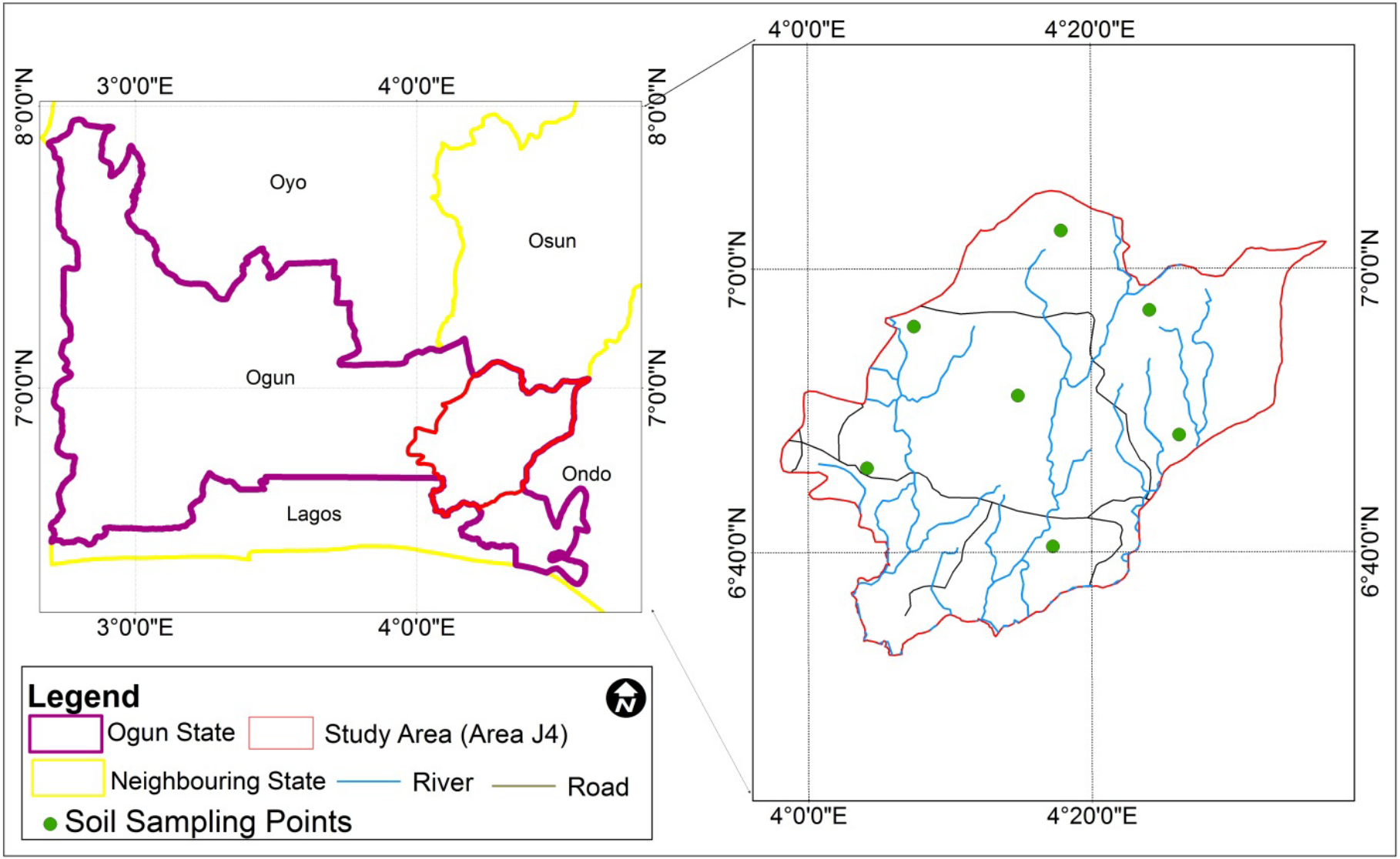


Figure 1: Location Map of Omo Forest Reserve, Area J4

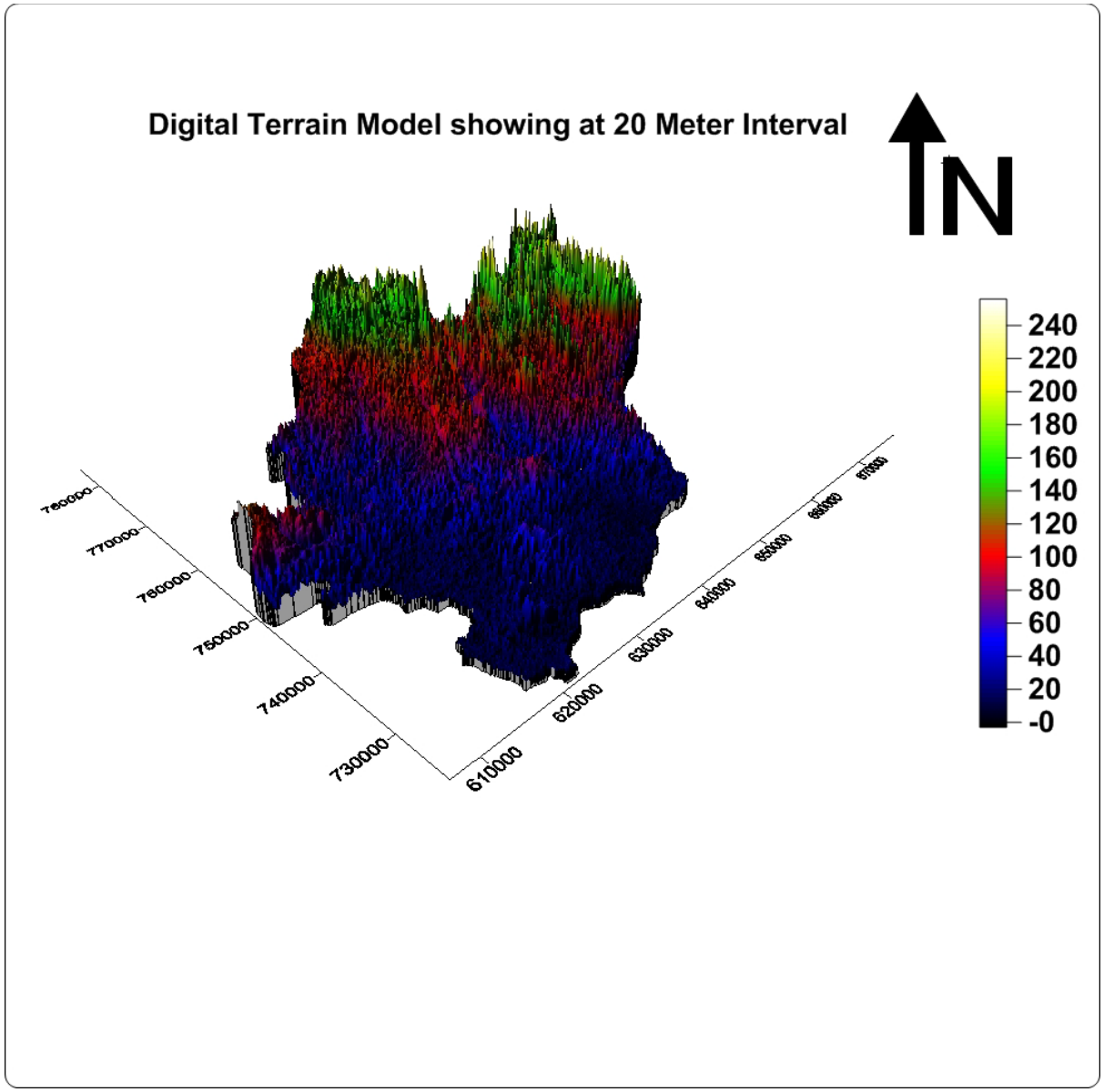


Figure 2: Omo Forest Reserve, Area J4 Digital terrain model

Table 1: Morphological characteristics of the Pedons under Teak (*Tectona grandis*) plantation at Omo Forest Reserve (Area J4), Nigeria

SS/Topo	Horizon Depth (cm)	Horizon Designation	Soil Texture	Soil Structure	Consistence	Soil Colour (Moist)	Mottles	Concretion	Horizon Boundary
UPP	0-40	A	GLS	MSAB	Fr,l	Dark brown (10YR3/3	Absent	Absent	cs
	40-155	B	SL	MSAB	Fi,hd	Reddish yellow (5YR 6/8)	Absent	Absent	-
MDD	0-35	A	LS	MSAB	Fi,l	Brown (7.5 YR 5/4)	Absent	Absent	cs
	35-150	Bt	GSCL	MSAB	Vfi, hd, l	Reddish yellow (5YR 6/8)	Absent	Absent	-
LS	0-40	A	GSL	MSAB	L, fr, shd	Dark brown (7.5 YR 3/2)	Absent	Absent	cs
	40-120	Bt	SCL	MSAB	l, fi ,shd	Red(2.5 YR 5/6)	Absent	Absent	--

SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam; GLS= Gravelly loamy sand
FSAB = Fine sub angular blocky; MSAB = Medium sub angular blocky;
CSAB= coarse sub angular blocky Fr = friable; Fi = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft, gs =gradual smooth; cs =clear smooth; cw =clear wavy

Table 2: Morphological Characteristics of the Pedons under *Gmelina* plantation at Omo Forest Reserve (Area J4), Nigeria

SS/Topo	Horizon Depth (cm)	Horizon Designation	Soil Texture	Soil Structure	Consistence	Soil Colour (Moist)	Mottles	Concretion	Horizon Boundary
UPP	0-36	A	GSCL	SG	l, fi shd	Reddish brown (5 YR 4/4)	Absent	Absent	Gs
	36-130	B	GSCL	MSAB	L, fr, shd	Yellowish red (5 YR 5/8)	Absent	Absent	-
MDD	0-27	A	SL	MSAB	Vfi ,l ,shd	Very dark brown (10 YR 2/2)	Absent	Absent	Cw
	27-101	Bt	GSCL	SG	Fi,l hd	Red (2.5YR 5/6)	Absent	Absent	Gs
	101-140	B2	SL	MSAB	Vfi, l ,hd	Yellowish red (5YR 5/8)	Absent	Absent	-
LS	0-58	A	SL	MSAB	Fi, l ,hd	Dark brown (7.5 YR 4/4)	Absent	Absent	Cs
	58-170	Bt	SCL	MSAB	Fi, l hd	Red (2.5 YR 4/8)	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, GSCL=gravely sandy clay loam
Fr = friable; Fi = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft, gs = gradual smooth; cw= clear wavy; cs =clear smooth;

Table 3: Physical properties of Pedons under Teak (*Tectona grandis*) plantation at Omo Forest Reserve (Area J4), Nigeria

Pedon	Horizon Depth (cm)	Horizon designa-tion	Sand g/Kg	Silt g/Kg	Clay g/Kg	Text-ural class	Gravel (g/kg)	Bulk density g/cm3	Ksat cm3/hr	Total porosity (%)	Clay DR	EC (dS/m)
Upper slope	0-40	A	850	28	122	LS	5335	1.22	5.90	116.15	6.65	1
	40 -155	B	790	18	192	SL	4425	1.22	0.65	38.71	7.96	2
Middle slope	0-35	A	830	48	122	LS	5845	1.47	1.12	23.45	6.04	0
	35-150	Bt	530	148	322	SCL	4665	1.04	2.27	459.30	5.89	1
Lower slope	0-40	A	750	128	122	SL	4260	1.16	3.60	75.09	3.72	2
	40-120	Bt	750	38	212	SCL	5560	1.45	IMP	22.26	6.47	1

Ksat= Saturated Hydraulic conductivity, EC= Electrical conductivity, CDR= Clay Dispersion ratio
IMP= impermeable

Table 4: Chemical properties of Pedons under Teak plantation (*Tectona grandis*) at Omo Forest Reserve (Area J4), Nigeria

Pedon	Horizon Depth (cm)	Horizon Designation	pH (H_2O)	pH (Kcl)	CEC/clay	OM %	OC %	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	0-40	A	5.33	4.00	4.68	1.78	1.04	0.11	10.94	0.38	2.44	2.60	0.45	54.99	0.12	5.99	95.27
	40-155	B	6.18	4.80	6.58	2.54	1.47	0.15	15.57	0.54	3.48	3.42	0.64	49.71	0.09	8.17	98.64
Middle slope	0-35	A	6.47	5.30	4.96	1.89	1.10	0.11	11.64	0.40	2.60	4.33	0.48	54.11	0.11	7.92	97.39
	35-150	Bt	5.40	4.40	2.89	1.07	0.63	0.07	6.59	0.23	1.48	1.44	0.27	51.47	0.14	3.56	95.13
Lower slope	0-40	A	5.31	5.50	2.96	1.10	0.64	0.07	6.74	0.23	1.50	1.57	0.28	57.63	0.15	3.73	94.04
	40-120	Bt	5.16	4.40	3.96	1.49	0.87	0.09	9.14	0.32	2.04	1.47	0.38	56.75	0.15	4.36	94.74

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

Table 7: Taxonomic Classification of soils on a Toposequence at Omo Forest Reserve (Area J4) Nigeria

Vegetation	Pedon No		USDA (2014)	FAO (2014)	Series
Teak					
	1		Typic Hapludalfs	Ferric Lixisols	Effon
	2		Typic Kanhapludalfs	Ferric Lixisols	Effon
	3		Typic Kanhapludalfs	Lixisols Hypereutic	Effon
Gmelina					
	4		Typic Kanhapludalfs	Ferric Lixisols	Effon
	5		Psammentic Kandiudalfs	EutricLixisols	Effon
	6		Typic Kandiudalfs	EutricLixisols	Effon

Results and Discussion

Soil Morphological Properties

3.1.1 Morphological properties of the Pedons under Teak plantation at Area J4

The morphological properties of the Pedon under teak plantation at area J4 was summarised in Table 1. The first pedon was located in the highest elevation of the toposequence of the site. The soil was deep with two horizons being identified. The soil colours were dark brown (10YR 3/3) and reddish yellow (5YR 6/8). The soil is characterised by gravelly loamy sand overlying sandy loam with clay content increase down the profile. Mottles and concretions were absent throughout the pedon. The soil had medium sub-angular blocky structure throughout the pedon.

The second pedon was located in the middle slope and it is characterised by loamy sand epipedon overlying gravelly sandy clay loam with clay content increase down the profile. The soil was also deep up to 150 cm. The soil colours were brown (7.5YR 5/4) and reddish yellow (5YR 6/8). The soil had medium sub-angular blocky structure throughout. Mottles and concretions were absent throughout the profile. Pegmatite was encountered at depth 150 cm.

The third pedon was located in the lowest elevation on the toposequence. The soil had gravelly sandy loam texture on the surface to sandy clay loam in the subsoil. The soil had colour variations from dark brown (7.5YR 3/2) to red (2.5YR 5/6). There was no evidence of mottles and concretions throughout the pedon. The soil had medium sub-angular blocky structure throughout the pedon. There was evidence of mica schists in all profiles under teak plantation at area J4.

Morphological characteristics of the Pedons under Gmelina plantation at Omo Forest Reserve (Area J4)

The morphological characteristics of the Pedons under Gmelina plantation also at Area J4 is shown in Table 2. The first pedon was located at the highest elevation on the toposequence. The soil was deep up to 130 cm. The soil is characterised by gravelly sand clay loam texture throughout the pedon. The soil colour are reddish brown (5YR 4/4) and Yellowish red (5YR 5/8). The soil had single grained structure on the surface and medium sub-angular blocky structure in the subsoils. There was no evidence of mottles and concretions throughout the pedon.

The second pedon was located in the middle slope of the toposequence. The soil was deep up to 140 cm and three horizons were identified. The soil colour variations ranged from very dark brown (10YR 2/2) on the surface soil to red (2.5YR 5/6) and yellowish red (5YR5/8) in the subsoils. The pedon is characterized by sandy loam on the epipedon through gravelly sandy clay loam to sandy loam subsurface horizon. The pedon had medium sub-angular blocky structure in first and last horizon with single grained structure in the second horizon. There were no mottles and concretions throughout the pedon.

The third pedon was located in the lower slope of the toposequence. The soil was also deep up to 170 cm depth. It is characterized by sandy loam overlying sandy clay loam subsurface soils. The pedon had medium sub-angular blocky structure throughout the pedon. The soil colours are dark brown (7.5YR 4/4) and red (2.5YR 4/8). Mottles and concretions were absent throughout the pedon.

Soil Physical Properties

The physical properties of Pedons under Teak (*Tectona grandis*) plantation at Omo forest reserve Area J4 is shown in Table 3. The soils are deep and moderately well – drained but despite that fact, two horizons were identified in each profile with uniform. Apart from the occurrence of relatively humus – rich ochric epipedon, no evidence of the existence of other pedogenic horizons were observed in the soils. The delineation of horizons within the profiles were based mainly on slight colour and textural variations, indicating that the sandy content of the soil were also high and decreased with increase in depth. The value ranged from 530 – 850 g/kg. The silt content decreased down the profile in the upper and lower slope profile while increased with increasing depth in the middle slope. The value ranged from 18 – 148 g/kg. The clay content increased with increasing depth. There was evidence of argilluviation in the middle and lower slope profiles. The textural class of the soil ranged from loamy sand, through sandy loam to sandy clay loam. The % gravel were also high may be because of the stony surface of the soil. The value ranged from 4260 – 5845 g/kg. The bulk density ranged from 1.04 – 1.47 g/cm^3 and it fluctuate through the profiles which could be attributed to clay content that increased with depth. The hydraulic conductivity (Ksat) ranged between 0.65 – 5.90 cm^3/hr. The last layer of lower slope profile was impermeable which could be attributed to high clay content in this horizon. The total porosity of the soil was considered high with the value ranged from 22.26 – 459.30%. The electrical conductivity ranged between 0 – 2ds/m which is an indication that soil is non-saline.

The chemical properties of Pedons under Teak plantation at Omo forest Reserve (Area J4)

The pH of the soil as shown in table 4 ranged from strongly acid to slightly acid (pH 5.3 – 6.47). The nitrogen content of the soil ranged from very low to low with the value ranged from 0.07 – 0.15%. The organic carbon ranged from low to moderate with value ranged between 0.63 – 1.47%. The organic matter ranged between low to medium had a value ranged from 1.1 – 2.54%. The available phosphorus had low to medium value which ranged between 6.59 and 15.57 mg/kg. The exchangeable calcium (Ca^{2+}) had the value ranged from 1.48 – 3.48 Cmol kg^{-1} while the exchangeable magnesium (Mg^{2+}) ranged from 1.44 – 4.33 Cmol kg^{-1} and exchangeable sodium (Na^{+}) ranged between 0.27 and 0.64 Cmol kg^{-1}. The CEC clay ranged from 2.89 – 6.58Cmol kg^{-1} while the effective cation exchange capacity (ECEC) ranged from 3.73 – 8.17 Cmol kg^{-1} which were considered to be low in the soil. The exchangeable acidity ranged from 0.09 – 0.15 Cmol kg^{-1}. The clay dispersion ratio ranged from 3.72 – 7.96. The silica ranged from 49.71 – 57.63%.

The percent base saturation ranged from 94.04 – 98.64% which were considered to be high. The micro – nutrients of the soil were generally high with Boron had a value range from 0.24 – 0.56 mgKg^{-1}, Manganese had the range between 22.8 – 104.96 mgKg^{-1}, Iron (Fe) ranged from 17.87 – 30.89 mgKg^{-1} while zinc (Zn) ranged from 14.12 – 24.02 mgKg^{-1}

The physical properties of pedon under Gmelina (G*melina arborea*) plantation at Omo forest Reserve Area J4

The soils of this area are also deep, between 130 – 170 cm depth and moderately well – drained with an almost uniform sandy clay loam texture, although a few horizons are of sandy clay loam texture of a relatively humus – rich ochric epipedon, no evidence of the existence of other pedogenic horizons were observed in the soils (Table 5). The delineation of horizons within the profiles were based mainly on slight colour and textural variations, indicating that the soils are young and that only very simple profiles have evolved. The sandy content of the soil was considered to be high ranged between 690 – 790 g/kg. The silt content were low to moderate and fluctuated through the profiles while the clay content was high and increased with increasing depth throughout the Pedons. In increasing trend of clay fraction with depth is an indication of clay translocation from top soil layer to lower layers (Opara, 2002). The textural class were sandy clay loam and a few horizons are of sandy loam texture. The gravel content ranged between 4035 – 6210 g/kg which were considered to be moderate – high. The bulk density ranged from 1.12 – 1.57 g/cm^3 and decreased down with increased depth. This is an indication of clay translocation from the overlying horizon (Mbagwu *et al*; 1984). Water transmission (Ksat) ranged from 0.53 – 2.79 cm^3/hr and it fluctuate throughout the profiles. The possible creation of water repellent properties may be due to accumulation and decomposition of leaf litters at the surface horizon. The decrease in Ks as the clay content increase down the depth indicating that the clay has a strong influence on water movement through the soil. The total porosity ranged between 28.64 – 243.24% and increased with increase depth. Porosity of subsurface soils was greater than in surface soil.

The electrical conductivity ranged between 1-3 dS/m which indicate non-saline soil. CDR values ranged from 3.18 – 6.46. Since CDR is a measure of soil macro aggregate stability with lower value implying higher stability (Opara, 2009).

The chemical properties of Pedons under Gmelina plantation at Omo forest reserve, Area J4

The soil pH ranged from strongly acidic to slightly acidic (pH 5.16 – 6.07). The total nitrogen of the soils were low with a range value of 0.05 – 0.13 %. The organic carbon contents of the soil varied from 0.43 – 1.25 % which were considered to be low to moderate. The organic matter content of the soil was also ranged between 0.74 and 2.14 %. The available phosphorus ranged from 4.54 to 13.13 mg/kg which were considered to be ranged from low to medium (Table 6). The exchangeable cations of the soil ranged from low to moderate. Exchangeable potassium (K+) ranged from 0.16 – 0.45 Cmol/kg^{-1}, Exchangeable calcium (Ca^{2+}) ranged between 1.02 – 2.94 Cmol/kg^{-1} while exchangeable sodium (Na^{+}) ranged 0.19 – 0.54 Cmol/kg^{-1}. The cation exchange capacity was considered to be very low to low with value ranged from 3.15 – 6.42 Cmol/kg^{-1}. The exchangeable acidity ranged from 0.12 – 0.16 Cmol/kg^{-1}. The percentage base saturation ranged from 92.62 – 97.95 % which was considered to be high.

The silica content of the soil ranged between 46.43 and 56.99 %. The available micro nutrients of the soil were considered to range from moderate to high. Boron ranged from 0.16 – 0.47 mgKg^{-1}, Manganese had the value ranged between 21.82 – 84.82 mgKg^{-1}, Iron (Fe) ranged from 19.16 – 33.91 mgKg^{-1} while Zinc (Zn) ranged between 10.27 and 21.82 mgKg^{-1}.

Omo Forest Reserve, Area J4, Soil classification

Based on criteria of USDA, soil Taxonomy (Soil Survey Staff, 2010, 2014), most of the Pedons clearly expressed Kandic horizon, Udic moisture regime. The soils had high base saturation, low CEC and clay content increases with depth, regular decrease in organic carbon with increase in depth is also observed. Therefore, all the pedons were classified as order Alfisols. The soils were classified as Udalfs based on the prevailing moisture regime at the suborder level.

Profile 1- exhibits the presence of ochric epipedon and Kandic horizon with base saturation >50% and moderate weathering which makes it to meet the requirements of soil order Alfisols. It has Udic moisture regime and this puts this pedon into sub-order Udalfs. A base saturation >50% and moderate weathering put it under Hapludalfs great-group and Typic Hapludalfs at sub-group level and as Ferric Lixisols (FAO/WRB, 2014). Profile 2- is classified as Alfisols and sub-order Udalfs for the same reasons as pedon 1 but it is placed in the Kanhapludalfs at the great-group level and Typic Kanhapludalfs at sub-group level. According to FAO/WRB, 2014, it is classified as Ferric Lixisols. Profile 3 – has similar horizon characteristics as pedon 2 above and therefore classified as pedon 2 but FAO/WRB, 2014 classified it as Lixisols Hypereutic based on percentage base saturation that is >90%. The soil had sandy loam texture on the surface to sandy clay loam in the subsoil. Profile 4 – this pedon shared similar characteristics with pedon 2 under teak plantation and therefore classified as pedon 2 both in soil Taxonomy and FAO/WRB, 2014.

Profile 5 – is classified as order Alfisols and sub-order Udalfs for the same reasons as pedon 1 to 4. The kandic horizon with high base saturation places it into Kandiudalfs great-group and high sand content with increase in depth puts it into Psammentic Kandiudalfs sub-group level and Eutric Lixisols (FAO/WRB, 2014). Profile 6 –is also classified as order Alfisols and sub-order Udalfs, great-group Kandiudalfs and Typic Kandiudalfs at sub-group level while according FAO/WRB, 2014, it is classified as Eutric Lixisols. At the soil series level, all the soils were deep, characterised by sandy loam overlying sandy clay loam with colour variations, there was evidence of mica schists in all profiles both under teak and *Gmelina* plantations and there were no mottling, no concretions throughout all the pedons, therefore, they all belong to Effon series. The summary is presented in the Table 7 below:

Conclusions

Omo forest reserve soils (Area J4) developed on basement complexes which formed from mica schists. It belongs to Mamu Association. At Omo Forest Reserve, Area J4, there was evidence of mica schists in all profiles both under teak and *Gmelina* plantations and there were no mottling, no concretions throughout all the pedons, therefore, they all belong to Effon series.

This study concluded that plantation existing on varying slope segments need to be managed differently to cater for topographic variations. The nutrient immobilization in the plantations would lead to decline in the soil nutrient status which would limit the productivity of plantations; therefore, there is a need to apply fertilizer to

replace nutrients immobilized by trees and those removed at harvest as also suggested by Aweto (1990) and Aweto and Enaruvbe (2010).

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