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Research Article

Characterization and pedogenetic study of soils of Onigambari Forest Reserve in South-West Nigeria

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Abstract: The use of forest resources requires accurate knowledge of land and soil properties. This necessitates detailed soil description and classification. This study was conducted to characterize and classify pedogenesis of Onigambari Forest Reserves in south-west Nigeria. A standard flexible rigid-grid method of survey was used to establish the mapping units. Three profile pits were dug under each land use type (Teak and Gmelina plantations), making six pits in the location. The profile pits were sampled at the pedogenic horizons for physical and chemical properties analyses. Soils obtained were classified using standard methods. The soils were classified as order Alfisols. Based on the moisture regimes, the soil belongs to Udalfs and Aqualfs suborder. At the great group level, the soil fell into the Kandic horizon. Under teak plantation, pedons 1 and 2 were classified as Plinthic Kandiudalfs (Eutric Lixisols), pedon 3 as Arenic Kandiaqualfs (Gleyic Lixisols) while under Gmelina, pedon 4 was classified as Typic Hapludalfs (Ferric Lixisols), pedon 5 Typic Kandiudalfs (EutricLixisols) and pedon 6 TypicKanhapluaqualfs (Gleyic Lixisols). At the soil series levels, pedons 1, 2, 4 and 5 belonged to Gambari series, pedons 3 and 6 belonged to Apomu series. Pedogenic processes identified were leaching, plinthization and desilication processes.

Keywords: Forest Resources, Teak Plantation, Gmelina Plantation, Pedogenesis, Alfisols

1. INTRODUCTION

Foresters have always relied on the knowledge of chemical and physical properties of soils to assess the capacity of sites to support productive forests. Recently, the need for assessing soil properties has expanded because of growing public interest in determining consequences of management practices on the quality of soil relative to sustainability of forest ecosystem functions in addition to plant productivity (Karlen *et al*., 1997). Pedogenesis can be defined as the process of soil development which was principally controlled by climate and vegetation (Bockheim *et al.,* 2005).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). These processes are carried out by the addition, removal, leaching, transformation and translocation of matter through a myriad of

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processes. All these processes affect horizon differentiation (horizonation) and soil development (Simonson, 1959).

Certini *et al*. (2001) and Shukla (2009) observed changes in morphological properties with forest establishment. The most significant pedogenic process that takes place in forest soils is the addition of organic matter, which is also the early step in the horizonation of most soils. They also confirmed that organic acids released by decomposing litter have more weathering impact than the root exudates and favour the formation of A horizons. Soil colour depends on pedogenic processes and parent materials from which the soil is formed. The quantity and nature of organic matter affects its interaction with soil particles, thus influencing soil colour (Schulze *et al*., 1993). Vegetation is a dominant factor in soil formation as it is the primary source of organic matter. Soil characterization and classification study under toposequence is essential to recognize the effects of these soil forming factors and processes on soil physicochemical and morphological properties and to draw promising management practices. This has not been properly addressed adequately studied on the basement of complex soils of forest reserves in south western Nigeria. This study is therefore, aimed at determining pedogenic processes and classifying the soils under teak and Gmelina plantations at the study site.

2. MATERIALS AND METHODS

2.1 The Study Area

The study was conducted at Onigambari Forest Reserve. Gambari Forest in the Oluyole Local Government area of Oyo State is situated between the River Ona on the west and the main motor road from Ibadan to Ijebu-Ode on the east. Onigambari Forest Reserve is located between latitude 7°26' + 7°55'N and longitude 3°53' + 3°90'E zones 31, and covering about 14,506.4 ha. The topography of the reserve is generally gentle undulating. The average altitude is from 121-152 m above the sea-level (Salami *et al.,* 2016).

The rainfall regime is double–peak and the mean annual rainfall is about 1300 mm. The mean annual temperature is about 27°C, with no marked seasonal or monthly departure from the annual average. The parent rock is Crystalline and it is a part of the Pre-Cambrian series shown as "undifferentiated basement complex" on the geological map of Nigeria. Most of the original forest at Onigambari has been clear-felled and subsequently replaced with teak and Gmelina, established by the 'taungya system'.

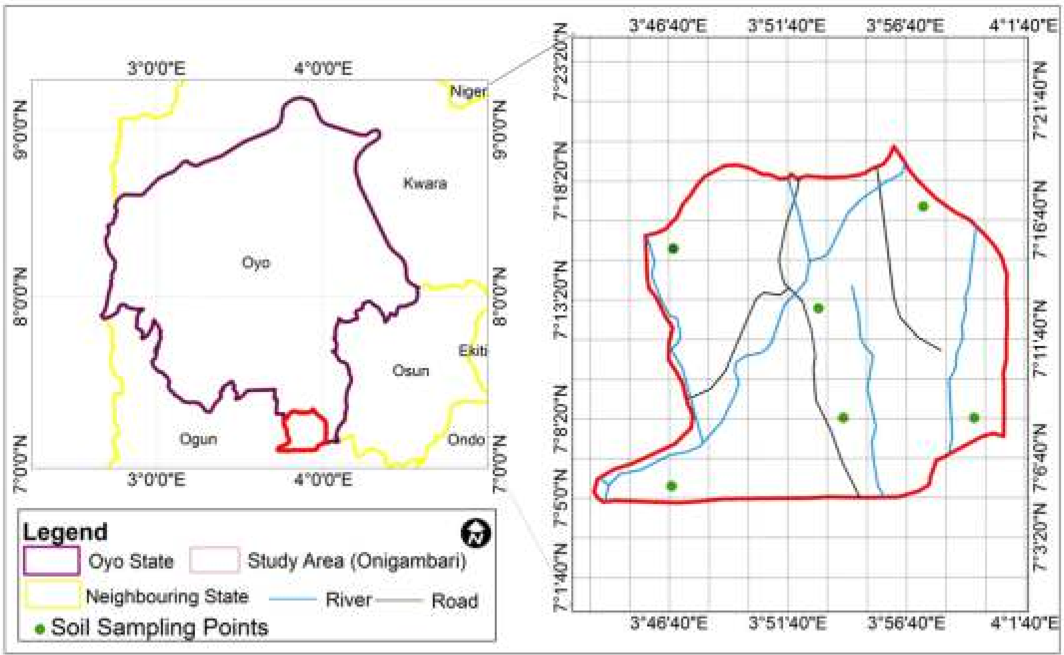

Figure 1: Location map of Onigambari forest reserve 2.2 Field Studies

Soil sampling was done using flexible rigid-grid sampling to cover the forest reserves. 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 is upper, middle and lower slope which will help to determine the topography of the study area (figure 2). Three profile pits were dug on each land use (Teak and Gmelina plantation), totaling six profiles in the location. The profiles were described using the guidelines of FAO (2006). Sampling of each profile was carried out according to the pedogenic horizons.

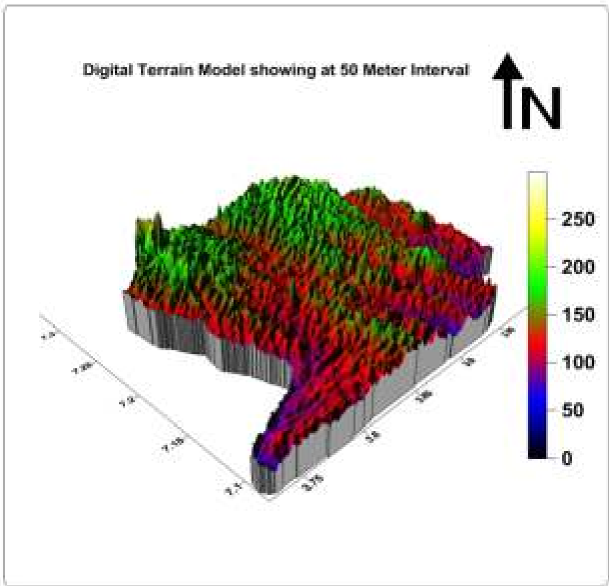

Figure 2: Digital Terrain Model of Onigambari Forest Reserve

2.3 Laboratory Analysis

The collected soil samples were air dried under room temperature. After air drying, some physical properties were carried out and subsequently sieved using a 2 mm sieve. The sieved soil samples were used for the laboratory determination of the soil properties. Particle size distribution was determined by the hydrometer method (Gee & Bauder, 1986). The soil pH was determined electrometrically in water using a ratio of 1:1 (10 g soil: 10 ml distilled water). Organic carbon was determined by the wet oxidation method (Walkley- Black, 1934) as described by Nelson and Sommers (1982). Total Nitrogen was determined using Kjeldahl digestion method. Exchangeable Ca, Mg, Na and K were extracted with 1M ammonium acetate (1M NH_4OAc) solution buffered at pH 7.0, as described by Anderson and Ingram (1993). Available phosphorus was extracted using the Bray No.1 method (Bray & Kurtz, 1945). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean (1965). Cation exchange capacity of the soil was determined with 1M NH_4OAc buffered at pH 7.0 (Chapman, 1965; Rhoades, 1982). The Effective Cation Exchange Capacity (ECEC) was obtained by the summation of exchangeable bases and exchange acidity (Somner & Miller, 1996). The Bulk density was determined using the core method (Anderson & 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 $gcm^{-3.}$ The electrical conductivity of the soil was taken using a standard electrical conductivity meter.

3. RESULTS AND DISCUSSION

3.1 Soil Morphological Properties

3.1.1 The Morphological Properties of the Pedons under Teak (*Tectona grandis*) Plantation at Onigambari Forest Reserve

The first pedon was in the upper slope of the toposequence. The soil was deep up to 150 cm depth. It had a colour variations ranging from dark brown (7.5 YR 4/4) on the surface to Yellowish red (5 YR 4/8) and yellowish brown (10 YR5/6) in the subsoils (Table 1). The oxidation of Fe in both surface and subsurface soils is indicated by the yellowish and reddish colour. Similar findings were reported by Foth (1990), who claimed that the presence of iron compounds in various states of oxidation is what causes the reddish and yellowish colour.

The profile had a sandy loam texture on the surface soil, overlying sandy clay loam subsoils with clay content increasing with increasing profile depth. The pedon had structure that varied from very fine sub-angular blocky on the surface soil to coarse sub-angular blocky in the subsurface horizons. Iron-manganese concretions were identified in the second and third horizons of the pedon. Black (5YR 2/1), common, medium and distinct mottles were observed at a depth of 45 cm to 150 cm. With an increase in depth, the mottles became many, very common, coarse and prominent with no changes in colour. The decreasing state of iron in the soil caused by alternating wet and dry circumstances over a long period of time may be the cause of the mottling that was seen in the soils (Eswaram *et al*., 2003).

The second pedon was in the middle slope of the toposequence also under teak plantation. The soil is characterized by sandy loam texture throughout the pedon. The soil was not deep due to the observance of a large iron pan at depth 60 cm. The soil colour varied from brown (7.5 YR 5/4) on the surface to yellowish red (5YR 4/5) in the second horizon. The soil had a very fine single grained structure up to depth 60 cm. The second horizon was very stony, which gave it a very coarse single grained structure. Few, medium and distinct black (5 YR 2/1) mottles were observed in the second horizon while iron-manganese concretion were observed in the two horizons identified. Iron pan covers the largest part of the area, which made soil profile to be shallow.

The third pedon was in the lower slope of the toposequence under teak plantation. The soil showed colour variation from dark brown (10 YR 4/3) on the surface, to light yellowish brown (10 YR 7/4) and yellow (10 YR 7/6). The soil was deep, but it was imperfectly drained with permanent water saturation at a depth of 150 cm, as at the time of profile sampling; whereas, sampling was done during the dry season (month of January). Black (5YR 2/1), common, fine and distinct mottles were encountered between 50 cm and 97 cm depth. The occurrence of black (5YR 2/1) mottle in the subsurface layer indicates poor drainage conditions.

This pedon had sandy loam texture throughout the profile. The soil structure varied from medium sub-angular blocky to coarse sub-angular blocky structure in the subsoils.

The changes in chemical and mineralogical composition, topographic positions, soil organic matter, texture, parent materials and moisture regimes may all be contributing factors to the observed variations in soil colour within and across pedons. Dengiz*et al.* (2012) reported a similar discovery and claimed that the difference in soil colour could be connected to OM, water logging, $CaCO_3$ buildup, and redox reaction in the soil.

Table 1:Morphological Characteristics of the Pedons under Teak Plantation at Onigambari Forest Reserve

SS/Topo	Horizon Designation	Horizon Depth (cm)	Soil Texture	Soil Structure	Consistence	Soil Colour (Moist)	Mottles	Concretion	Horizon Boundary
UPP	A	0-45	SL	FSAB	L ,fr ,shd	Dark brown(7.5YR4/4)	Absent	Absent	Cw
	Btc1	45-85	SCL	CSAB	Fi,hd	Yellowish red(5YR4/8)	5YR2/1c, m, d	Fe-Mn	Cw
	Btc2	85-150	SCL	CSAB	Vfi, hd	Yellowish brown (10YR5/6)	5YR2/1 m, cr, pr	Fe-Mn	-
MDD	A	0-30	SL	SG	l. fr	Brown (7.5YR5/4)	-	Fe-Mn	Gs
	Bc	30-60	SL	SG	l, fr	Yellowish red(5YR4/6)	5YR2/1 fw, me,d	Fe-Mn	-
LS	A	0-50	SL	MSAB	Fr ,shd	Dark brown(10YR4/3)	Absent	Absent	Gs
	Bc	50-97	SL	MSAB	Fr, shd	Light yellowish brown(10YR7/4)	5YR2/1 c, fi,d	Fe-Mn	Gs
	B2	97-150	SL	CSAB	Fi, shd	Yellow(10YR7/6)	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
\+ Fr = friable; Fm = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft, c= common, m= medium, d= distinct, m= many, cr= coarse, pr= prominent, gs= gradual smooth, cs= clear wavy, fw= few, me= medium

3.1.2 The Morphological Characteristics of the Pedonsat Onigambari Forest Reserve under Gmelina Plantation (*Gmelina arborea*).

The first pedon was located at the upper slope of the toposequence. The surface soil colour was yellowish red (5YR 4/6) and it had the sandy loam texture. The soil surface was slightly stony and had medium subangular blocky structure. No mottles were observed but it can be deduced that prolong iron-manganese concretions exposed to alternating wet and drying conditions, led to the formation of iron pan encountered. The second pedon was also in the middle slope under Gmelina plantation. Only two horizons were identified in this pedon due to the observance of yellowish brown plinthite nodules that form very hard iron pan at a depth below 80 cm. The soil is characterized by sandy loam epipedon overlying sandy clay loam subsurface horizon. The soil had colour variations from dark brown (7.5YR 4/2) to reddish brown (5 YR 4/4). Many medium, prominent black (5 YR 2/1) mottles were observed at depth between 35 cm - 80 cm (i.e. 2nd horizon). The soil structure ranged from medium sub-angular blocky to fine single grain in the subsoils. The subsoils were very stony. The third profile was located at the lower slope. The soil was deep and had colour variations from very dark brown (7.5 YR3/4) on the surface to brown (7.5YR 5/4) and light gray (10 YR 7/1) in the subsurface soils. The soil is characterized by sandy loam in the first and second horizon overlying sandy clay loam subsurface soils. The soil had structure ranging from medium sub-angular blocky to single grained to thin platy in the subsoils. Black (5 YR 2/1), common and medium mottles were observed in the second horizon. Quartz igneous rock was encountered at depth 110 cm as shown in Table 2.

The soils that were being studied had erratic A and B layers and varied in depth from somewhat shallow to deep (Tables 1and 2). The upper pedons on Gmelina plantation had the shallowest depths (0-30 cm) among the topographic positions. Generally, the thickness of the soils increases down topographic positions. Soils on all the topographic positions showed considerable similarity in the presence of colour variations, mottles and sequence of master horizons, where every pedon has B master horizon showing illuviation of silica, silicate clays, plinthization and iron-concretions, under A master horizon, altered by vegetations and other types of disturbance.

Table 2: Morphological Characteristics of the Pedons under Gmelina Plantation at Onigambari Forest Reserve

SS/Topo	Horizon Depth (cm)	Horizon Designation	Soil Texture	Soil Structure	Consistence	Soil Colour (Moist)	Mottles	Concretion	Horizon Boundary
UPP	0-30	Av	SL	MSAB	Fr, shd	Yellowish-red(5YR4/6)			
MDD	0-35	A	SL	MSAB	Fr, shd	Dark-brown(7.5YR4/2)	Absent	Absent	Cs
	35-80	Bc	SCL	SG	Fi ,shd	Reddish-brown(5YR4/4	10YR5/8	Fe-Mn	-
LS	0-22	A	SL	MSAB	Fr, hd	Very dark - brown(7.5YR3/4	Absent	Absent	Cs
	22-90	Bc	SL	SG	l,	Brown(7.5YR5/4)	5YR2/1	Fe-Mn	Cs
	90-110	Bt	SCL	PL	Vfi ,hd	Light-gray(10YR7/1)	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
\+ Fr = friable; Fm = Firm; l = loose; hd= Hard; shd = Slightly hard, s = soft

3.2 Soil Physical Properties

3.2.1 The Physical Properties of Pedons under Teak (*Tectona grandis*) Plantation at Onigambari Forest Reserve (Table 3)

The upper and lower slope pits were deep (150 cm depth each) while the middle slope pit was shallow, about 60 cm in depth, due to the presence of hard pan at this depth. The sand content of the soils was considered high, with values decreasing down the profile in the upper slope and fluctuating in the lower slope. The same content was observed in the two layers of the middle slope. In the higher slope, the silt content increased while decreasing in the middle and lower slopes of the profile.

The clay content increased down the profiles with increasing depth in all profiles. But there was no evidence of argilluviation in the middle and lower slope profiles. The textural class of the soils ranged from sandy loam to sandy clay loam and the texture does not change with depth in the middle and lower slope. The gravel content of the soils was considered high with values ranging from 109.5 – 754.5 g/kg. It increased by depth which, this is an indication that total pore space is reduced and plants are more likely to be susceptible to the effect of drought (McKenzie *et al.,* 2002).

The bulk density of the soils ranged from 1.06 – 1.50 g/cm3, which is a good indication that the soil is suitable for root growth and soil permeability (Cresswell & Hamilton, 2002). The bulk density decreased with increasing depth in all profiles. For the optimal crop production, these values will enable root penetration, excellent aeration and water circulation (Esu, 2010).

The electrical conductivity (EC) of the soils ranged between 1 and 3 dS/m. This is an indication of slightly saline soil and with this condition, plant available water would not be affected and no cause for plant stresses (Krista, 2003). This range is classified as low by Havlin *et al*. (1999), which suggests that the soils are not affected by salt.

Table 3: Physical Properties of Pedons under Teak Plantation at Onigambari Forest Reserve

Pedon	Horizon (cm)	Depth	Horizon designation	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Gravel (g/kg)	Bulk density g/cm3	Ksat cm^3/hr	Total porosity (%)	Clay Disp. Ratio	EC (dS/m)
Upper slope	1 – 45		A	790	88	122	SL	1095	1.47	1.17	41.50	7.19	2
	45 -85		Btc1	650	148	202	SCL	5140	1.35	0.51	45.28	4.13	1
	85 -150		Btc2	690	108	202	SCL	7545	1.30	1.02	44.91	5.46	1
Middle slope	0-30		A	810	68	122	SL	2200	1.45	1.30	41.13	4.86	1
	30-60		Bc	810	18	172	SL	7480	1.36	0.99	43.02	5.66	1
Lower slope	0-50		A	760	88	152	SL	2320	1.50	0.67	42.64	4.13	2
	50-97		Bc	830	8	162	SL	5450	1.39	0.61	42.64	6.78	2
	97-150		B2	790	28	182	SL	5245	1.06	0.61	43.40	5.46	3

EC= Electrical conductivity

3.2.2 The Physical Properties of Pedons under Gmelina (*Gmelina arborea*) at Onigambari Forest Reserve (Table 4)

The depth of lower slope profile was 0 – 110 cm, while the upper and middle slope profiles were shallow with the upper slope too shallow at about 30 cm, before hard pan/Iron pan was encountered. The soil was generally characterized by high sand content with the upper slope having 830 g/kg sand, while decreasing the profile of the lower slope, the value decreased the middle slope's profile.

The silt content fluctuated down the profiles while the clay content increased depth but, there was no evidence of argilluviation. The textural class of the soil ranged between sandy loam and sandy clay loam. The gravel content was generally high (930 – 803.0 g/kg). The bulk density of the soil ranged between 1.09 – 1.48 g/cm^3, which indicates good soil suitable for root growth. The bulk density decreased in the profiles. Because Kachinkii (1965) recommended over 50% for good soils, between 45 and 50% satisfactory soils, 40 to 45% for unsatisfactory soils, and under 40% and below for poor soils. Also, according to Brady and Weil (2002) the ideal total pore space values, which are acceptable for crop production are around 50%. The soils, both under teak and Gmelina plantations, have unsatisfactory porosity with values ranging from 40 to 45%. This could be ascribed to the high sand and gravel contents in the top soils and sub-soils, which largely include macro pores that typically cannot hold water against gravity and are typically filled with air.

The electrical conductivity value ranged from 1 – 9 dS/m, the upper and middle slopes had between 1 -2 dS/m (non-saline) while the lower slope values ranged between 1 and 9 dS/m, which is an indication that the soil is between non-saline and strongly saline. This can affect soil physical properties by causing fine particles to bind together into aggregates, a process known as flocculation. At the same time, this is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels, salinity can have negative and potentially lethal effects on plants (Krista, 2003).

Table 4: Physical Properties of Pedons under Gmelina Plantation at Onigambari Forest Reserve

Pedon	Horizon Depth (cm)	Horizon designation	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Gravel (g/kg)	Bulk density g/cm³	Ksat cm³/hr	Total porosity (%)	CDR	EC (dS/m)
Upper slope	0-30	Av	830	18	152	SCL	930	1.47	0.89	42.26	6.01	2
Middle slope	0-35	A	730	108	162	SL	5990	1.47	0.59	43.40	6.96	1
	35-80	Bc	770	28	202	SCL	5390	1.37	1.51	43.40	4.12	1
Lower slope	0-22	A	810	38	152	SL	2355	1.48	0.69	44.15	5.46	3
	22-90	Bc	790	48	162	SL	8030	1.41	1.42	42.26	3.65	1
	90-110	Bt	750	28	222	SCL	5055	1.09	0.39	43.02	6.19	9

Ksat= Hydraulic conductivity, CDR= Clay Dispersion ratio, EC= Electrical conductivity

3.2.2 The Chemical Properties of Pedonsunder Teak Plantation at Onigambari Forest Reserve (Table 5)

The reaction of the soil profiles ranged from moderately acidic to slightly acidic (pH 5.8 – 6.5). In the range of 0.08 to 0.11%, the total nitrogen contents of the soil are very low and low. Between 0.1 and 0.2% of total nitrogen is regarded as low, and less than 0.1% as very low (Landon, 1984). The high temperature of the tropical environment, which causes a rapid loss of soil nitrogen owing to volatilization, is one of its primary characteristics (Olowolafe & Dung, 2000). Leaching caused by periods of heavy rainfall in this environment also contributed to nitrogen losses.

The percentage of organic matter ranged between 1.2 – 1.77 which were considered to be low in all the pedons. Available phosphorus ranged from low to medium, with values ranging from 7.15 – 10.89 mg/kg. The exchangeable cations generally ranged from low to moderate. Effective cation exchange capacity was considered to be very low, less than 16 Cmol/kg-^{1}; the percentage base saturation values were generally high (> 50%).

3.2.3 The Chemical Properties of Pedonsunder Gmelina at Onigambari Forest Reserve

The pH of the soil ranged from moderately acidic to slightly acidic (pH 5.8 – 6.2) (Table 6). The nitrogen contents of the soils were low with value ranging from 0.1 – 0.17%. The organic carbon content ranged from low to moderate with values ranging between 0.88 and 1.57%. The values increased in depth. The outcomes are in line with the conclusions of Wakene and Heluf (2003), who indicated that anthropogenic activities and continuous cultivation caused OC oxidation and subsequently led to a decrease in TN. The available phosphorus contents of the soils were moderate with values ranging from 9.34 – 16.58 mgKg^{-1}. Generally, the exchangeable cations contents ranged from moderate to very high except for calcium Ca^{2+}, which was considered low in the soil. The exchangeable Ca^{2+} ranged from 2.09 – 3.70 Cmolkg^{-1}. The CEC clay ranged from 3.38 – 6.98 Cmolkg^{-1} while the effective cation exchange capacity (ECEC) ranged between 7.16 and 19.75 Cmolkg^{-1}. The soil's CEC is typically thought to be poor both under teak and Gmelina vegetations. Between 7.16 to 19.75 cmolkg-1 were the values. According to Jim (2003), the low CEC values from all the pedons are a reflection of the low levels of soil organic carbon and kaolinitic clay. From the obtained, it was observed that all pedons had high percent-based saturation (>50%). This does not imply that the soils have high levels of basic cations, but rather, it shows that the exchange site will be easily saturated due to the kaolinitic clay's low capacity to adsorb cations and the few available bases (Kparmwang*et al.,* 1998).

Micronutrients

All pedons' available micronutrient contents (Fe, Mn, Zn, and B) exhibit erratic trends with respect to soil depth and slope (Table 5 and 6). All of the pedons had extremely high concentrations of available Fe and Mn, compared to Zn and B. The amount of organic matter in the soil, the reactivity of the soil and the amount of clay, are the three main factors that affect the micronutrient content of soils (Fisseha, 1992).

The range of Fe, Mn, Zn and B concentrations in all the pedons was 23.04 mgkg^{-1} to 31.96 mgkg^{-1}, 41.56 mgkg^{-1} to 63.32mgkg^{-1}, 12.43 mgkg^{-1} to 22.98 mgkg^{-1} and 0.26 to 0.39 mgkg^{-1} respectively (in the teak plantation) and 16.58mgkg^{-1} to30.52 mgkg^{-1}, 54.31 mgkg^{-1} to 96.39 mgkg^{-1}, 15.60 mgkg^{-1} to 21.65 mgkg^{-1}and 0.33 mgkg^{-1} to 0.59 mgkg^{-1} respectively under Gmelina plantation.

Table 5 : Chemical Properties of Pedonunder Teak Plantation at Onigambari Forest Reserve

Pedon	Horizon Depth (cm)	Horizon Designation	pH (H_2O)	pH (Kcl)	CEC/ Clay (cmol /Kg)	OM %	OC %	N %	P mg/kg	K^+	Ca^{2+}	Mg^{2+}	Na^+	H+	ECEC	B.S %	Silica %
													(Cmol/Kg)				
Upper slope	0-45	A	6.40	5.41	3.30	1.26	0.73	0.08	7.71	0.27	1.73	2.77	0.32	0.09	5.18	97.34	57.87
	45-85	Btc1	6.00	4.38	4.35	1.66	0.96	0.10	10.16	0.35	2.27	5.60	0.42	0.11	8.75	97.50	49.07
	85-150	Btc2	6.30	5.81	3.34	1.26	0.74	0.08	7.75	0.27	1.73	2.19	0.32	0.11	4.62	96.71	52.59
Middle slope	0-30	A	6.10	5.31	3.14	1.20	0.69	0.07	7.33	0.25	1.64	3.83	0.30	0.08	6.10	97.33	56.99
	30-60	Bc	6.30	5.56	3.07	1.17	0.68	0.07	7.15	0.25	1.60	2.24	0.30	0.09	4.48	97.18	59.63
Lower slope	0-50	A	6.50	5.41	3.27	1.25	0.72	0.08	7.65	0.26	1.71	3.22	0.32	0.08	5.59	97.43	55.23
	50-97	Bc	6.00	5.52	4.62	1.77	1.03	0.11	10.89	0.38	2.43	5.89	0.42	0.08	9.20	98.00	64.02
	97-150	B2	5.80	5.74	3.61	1.38	0.81	0.09	8.50	0.29	1.90	4.40	0.35	0.06	7.00	97.99	55.23

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 5: Chemical Properties of Pedon under Teak Plantation at Onigambari Forest Reserve cont'd

Pedon	Horizon Depth(cm)	Horizon Designation	B	Mn ($mgkg^{-1}$)	Fe	Zn
Upper slope	0-45	A	0.28	44.87	29.44	16.18
	45-85	Btc1	0.37	59.20	23.04	14.83
	85-150	Btc2	0.28	45.11	30.26	12.45
Middle slope	0-30	A	0.26	42.61	32.16	22.98
	30-60	Bc	0.26	41.59	30.64	19.88
Lower slope	0-50	A	0.28	44.52	31.96	17.91
	50-97	Bc	0.39	63.32	25.15	15.79
	97-150	B2	0.30	49.44	25.17	16.75

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Boron, Mn=Manganese, Fe=Iron, Zn=Zinc.

Table 6: Chemical Properties of Pedons under Gmelina Plantation at Onigambari Forest Reserve

Pedon	Horizon Depth (cm)	Horizon Designa t-ion	pH (H_2O)	pH (Kcl)	CEC/clay (cmol/kg)	OM %	OC %	N %	P mg/kg	K^+	Ca^{2+}	Mg^{2+}	Na^+	H+	ECEC	B.S %	Silica %
													(cmol/kg)				
Upper slope	0-30	Av	5.80	5.40	5.13	1.98	1.16	0.12	12.19	0.42	2.72	3.45	0.50	0.07	7.16	98.69	60.51
Middle slope	0-35	A	6.20	5.49	3.38	1.52	0.88	0.10	9.34	0.32	2.09	5.60	0.39	0.09	8.49	97.90	59.63
	35-80	Bc	6.20	5.59	5.45	2.10	1.22	0.13	12.90	0.44	2.88	8.29	0.53	0.07	12.21	98.79	52.59
Lower slope	0-22	A	5.80	6.09	5.59	2.16	1.26	0.13	13.26	0.46	2.96	6.28	0.54	0.07	10.31	98.88	54.35
	22-90	Bc	6.40	5.67	5.71	2.20	1.28	0.13	13.54	0.47	3.02	15.6	0.56	0.07	19.75	98.54	48.19
	90-110	Bt	5.80	5.32	6.98	2.70	1.57	0.17	16.58	0.57	3.70	9.29	0.68	0.06	14.30	99.08	56.99

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 6: Chemical Properties of Pedon under GmelinaPlantation at Onigambari Forest Reserve cont'd

Pedon	Horizon Depth(cm)	Horizon Designation	B	Mn	Fe	Zn
			(mgkg^{-1})			
Upper slope	0-30	Av	0.43	70.91	24.17	15.67
Middle slope	0-35	A	0.33	54.31	28.55	15.84
	35-80	Bc	0.46	75.04	26.09	21.05
Lower slope	0-22	A	0.46	77.10	30.52	19.01
	22-90	Bc	0.49	78.76	24.60	15.60
	90-110	Bt	0.59	96.39	16.58	21.65

3.3 Soil Classification

The soils of the study area were classified using the USDA Soil Taxonomy (Soil Survey Staff, 2010, 2014) and FAO/UNESCO (2014). The differentiating properties used for the classification included some morphological, physical and chemical properties. the pedons exhibit Ochricepipedon and clearly expressed Kandic and ArgillicBt horizons. The soils had high base saturation, low CEC and clay content increases with depth, regular decrease in organic carbon with increasing depth. This meets the requirements of soil order Alfisols. The moisture regime is Udic and this puts the pedons into suborder Udalfs.

3.3.1 Profile1—has Argillic horizons with concretions, CEC < 16 cmol/kg, ECEC >16 cmol/kg; putting it under order Alfisol, suborder Udalfs having Udic moisture regime and Base saturation greater than 50% (97.34%). Increase in silt content with increasing depth with iron-manganese concretion identified at the 2nd and 3rd horizons put it under great-group Kandiudalfs and sub-group Plinthic Kandiudalfs (EutricLixisols) Sedentary soil and soil colour ranged from dark brown to yellow-red and yellowish-brown. Mottles were observed at depths (45 – 150 cm). The soil had a sandy loam texture overlying sandy clay loam with clay content increased down the profile. This sand content was high and decreased in the profile while the silt content increased down the profile. The gravel content was high and increased with increasing depth (Gambari series).

Profile 2--- has placic horizons, CEC 6.21 cmol/kg, ECEC 10.58 cmol/kg, Base saturation 97%, Udic moisture regime. This meets the requirement of order Alfisol and sub-order Udalfs, with the soil having 25% or more plinthite which has led to large iron pan, therefore putting the soil at great group Kandiudalfs and Plinthic Kandiudalfs sub-group. Sedentary soil; the soil was not deep due to large iron pan/ironstone at a depth 60 cm. The soil colour varied from brown to yellowish-red. Mottles and Fe-Mn concretions were observed. Soil texture was sandy loam throughout the profile. Consistency was loose and friable throughout. Second horizon was very stony and large iron pan covers the largest part of the area, which made soil profile to be shallow, therefore, classified as Gambari series.

Profile 3—this pedon classified as order Alfisol for the same reasons as pedon 1 and 2. The presence of aquic moisture regime places this pedon in sub-order aqualfs, great-group Kandiaqualfs and Arenic Kandiaqualfs sub-group. The soil showed colour variations from dark brown to light yellowish brown and yellow in the subsoil. Mottles were observed. The soil was deep but imperfectly drained with permanent water saturation at a depth of 150 cm. It had sandy loam texture throughout. The sand content was high; silt content decreased while clay content increased with increasing depth, the gravel content was also high, therefore classified as Apomu series. Pedon **4** is also classified as order Alfisol and sub-order Udalfs for the same reasons as pedon 1 to 3 above. The predominance of plinthite in the surface horizon, which had led to hardpan places this soil in the great group Hapludalfs and Plinthic Hapludalfs sub-group, Plinthosol (FAO/WRB, 2014). The soil was to too shallow, a large iron pan was encountered at a depth 30 cm. this soil colour was yellowish red. It had sandy loam textured soil surface which was slightly stony. It has high sand content with fluctuating silt content while clay content increased with increasing depth. The textural class ranged from sandy loam to sandy clay loam and therefore, classified as Gambari series.

Profile 5 classified as order Alfisol and sub-orders Udalfs, great-group Kandiudalfs for the same reasons as other pedons above. There was presence of plinthite in the sub-surface horizons with sharp increase from a depth of 30 cm and a value exceeding 60%, placing this pedon in the sub-group Plinthic Kandiudalfs. According to FAO/WRB(2014), the soil is classified as Plinthosol. The soil colour ranged from dark brown to reddish brown. Very hard iron pan was encountered at a depth below 80 cm. Mottles were present, had sandy loam overlying sandy clay loam and subsoil was very stony. Sand content decreased down the profile while clay content increased with increaseing depth and fluctuating silt content, therefore classified as Gambari series.

Profile 6 are classified as Alfisols, sub-order aqualfs having an aquic moisture regime. It is placed under Kanhapluaqualfs at great-group level and Typic Kanhapluaqualfs at sub-group level. Hill-wash soil, deep, colour varied from very dark brown to brown and light gray. Mottles were observed. The soil is characterized by sandy loam and sandy clay loam. Quartz was encountered at 110 cm depth. Sand content decreased down the profile, silt content fluctuates while clay content increased with increasing depth, and itis therefore classified as Apomu series.

4 CONCLUSION

The results of the study showed that the dominant pedogenic processes under plantations were leaching, plinthization and desilication. The largest part of the soils was occupied with large iron pans. The soil was to too shallow especially the upper and middle slopes under both plantation (land use type). The gravel content was high and increased with increase in depth. This study suggests that appropriate soil management need to be adopted to avoid impedance to root growth or restriction of root growth.

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