Asian Journal of Agricultural Sciences 4(1): 16-25, 2012
ISSN: 2041-3890

Submitted: July, 02, 2011 Accepted: September, 18, 2011 Published: January, 25, 2012

Pedogenesis and Classification of Soils Under Teak (*Tectona grandis* Linn. f) Plantation of Various Ages in the Southern Guinea Savanna of Nigeria

A.M. Samndi and J.M. Jibrin
Department of Soil Science Faculty of Agriculture Bayero University Kano Nigeria

Abstract: Plantation trees play a major role in soil formation and development, thus this stimulated the need to determine the effects of *Tectona grandis* in pedogenic processes and to classify the basaltic soils of the Jos Plateau underneath trees of various ages. The study showed that the main pedogenic processes were braunification, mineralization and lessivation. Floral pedoturbation encouraged illuviation, thus resulting into the formation of clay films on ped surfaces and Bt horizons. The soils were reddish brown to dark reddish brown with hues between 2.5 to 5YR and chroma less than 4. The texture varied from gravelly clay loam to gravelly clay, the structure ranged from weak fine to moderate subangular blocky and non sticky to sticky consistence with aging plantations. The soil pH slightly varied between 5.6 and 6.3 with plantation age and soil depth. Organic C content did not reveal a definite trend with plantation age, though values were lower in subsurface horizons and decreased with depth. Available P and Total Exchangeable Bases (TEB) linearly decreased with aging plantations. The lowest TEB value (8.52 cmol(+)/kg) was obtained under the oldest tree stands. The exchange acidity (Al and H) value was highest (2.40 cmol(+)/kg) in the underlying horizons under the oldest plantation, thus indicative of the deteriorative effects of trees on the soil properties. The soils were classified using the USDA soil taxonomy as Humic Dystrustept (11year old), Oxic Dystrustept (21year old), Kanhaplic Haplustult (31 year old) and Typic Haplustult (36 year old). Using the FAO/UNESCO the soils were classified as Humic Cambisols (11 and 21 years old), Humic Acrisols (31year old) and Chromic Luvisols (36 year old). Applying the WRB, the soils were classified as Chromic Umbrisols (11 and 21 years old), Umbrihumic Acrisols (31 year old) and Chromic Luvisols (36 year old).

Key words: Classification, plantation, pedogenesis, *Tectona grandis*

INTRODUCTION

Plantation trees, bring about changes in edaphic, microclimatic, floral, faunal 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 myriad of processes. All these processes according to Simonson (1959) affect horizon differentiation (horizonation) and soil development. Certini *et al*. (2001) observed that after 30 years of Etnean broom and pine establishment, soils developed had differences in morphological, mineralogical and chemical properties. Similarly Shukla (2009) reported 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 horizonation of most soils. Stevenson (1982) reported that Water-soluble organic compounds from decomposing leaf litter play an important role in the cycling of metals and in the chemistry of forest soil formation. Certini *et al.* (2001) confirmed that organic acids released by decomposing litters, have more weathering impact than the root exudates and also favours the formation of A/C horizons.

Other major soil forming processes include are eluviation (acid leaching) and humification (Duninget *et al*., 1986). Leaching losses are those of materials such as Ca, Mg and K, which leave the soil through solution. William (1979) confirmed a decrease in Ca, K and Mg concentrations from surface litter to that of humus layer and subsequent increase in aluminium content with depth indicating that the bases were leached to a greater extent than other elements. These processes according to Wilde (1957), exerts a direct influence upon the morphology of the soil profile, which over time transform embryonic soils into genetically developed or matured soils.

Blevins *et al.* (1970) observed that soil matrix adjacent to tree roots (within 1 to 2 mm), contained fine - grain materials with consequent pore - size distribution shift towards smaller pore diameter (50-20 μ or less). Reitam (2001) reported that after 30 years of forest establishment on quarry detritus, coarse particles weathered and resulted in increased accumulation of clay in the thin horizon with silt beneath it. Soil colour

Corresponding Author: A.M. Samndi, Department of Soil Science Faculty of Agriculture Bayero University Kano Nigeria

depends on pedogenic processes and parent materials from which the soil is formed. The quantity and nature of organic matter affects it interaction with soil particles, thus influencing soil colour (Schulze *et al*., 1993).

Similarly, Armson (1977) observed that the intensity of soil colour was determined by the amount and the degree of organic matter decomposition. Shukla (2009) observed that after 23½ years of teak establishment, soil colour changed from 7.5YR 4/4 to 5YR. Folster *et al.* (1971), postulated that biogenetic processes of soil colouration are due to mechanical mixing by plant roots and fauna (turbatution). Soil structure has been reported to be influenced by plantation establishment. Okoli Paul and Wilson (1982), Chaney and Swift (1986), observed that humic carbon is associated with an increase in the size and grade of crumbs in the soil which in turn improves soil structure and aggregate stability. Similar observation was made by Shukla (2009), who reported improved soil structure, with consistency of slightly sticky and slightly plastic after 23½ years of teak establishment.

Soil pH under trees generally decreased as a result of organic acids released by decomposing litters and exchangeable cation uptake (Ohta, 1990). Similar decrease in soil pH was observed by Russell *et al*. (2007), which was attributed to advanced weathering of the soil and cation storage by tree biomass. Owusu-Bennoah *et al.* (2000) corroborated that vegetation builds up a store of nutrients particularly N, P, Ca and K in organic materials that accumulate on the surface soil, which are later recycled after decomposition. This observation was also confirmed by Junge andSkowronek (2007) that vegetation acts as ion pump, concentrating nutrients in their litters, which are later released on decomposition. Vegetation as a soil forming factor has not being properly addressed particularly adequately studied on the basaltic soils of the Jos plateau. This study is therefore, aimed at determining pedogenic processes and classifying the soils under teak plantation of various ages on the basaltics soils of the Jos plateau.

MATERIALS AND METHODS

Setting of the study area: The study was conducted in Nimbia Forest Reserve located in Jema'a local government area of Kaduna state of Nigeria within Southern Guinea Savanna. The reserve covers an area of about 2,282.4 ha and lies between longitudes 8º30′ and 8º31′ E and latitudes 9º29′ and 9º31′ N, with an elevation of about 600 m above sea level. Nimbia Forest Reserve is located within the Jemma'a platform under lain by igneous and metamorphic rocks. The soil belongs to the Nimbia series, developed from weathered olivine basalt and classified as Eutrophic brown soils by D'Hoore (1964), while Ezenwa (1988) classified the soils as Ultic Paleustalfs, Plinthusalfs and Plinthustults. The position of Nimbia with respect to its altitude (600 m), induces orographic rain with mean annual rainfall of about 1260 mm and mean annual temperature of about 21.7ºC.

Field studies: Soil sampling for the study was conducted in June 2004, where unpublished semi-detailed soil survey report by Howard (1963) and planting record maps were used in the preliminary site selection for the study. From the reports, areas described as Nimbia clay were investigated under the following planting years: 1990 (11 years), 1980 (21 years), 1970 (31 years) and 1965 (36 years). A total of 12 pedons were located within the various planting periods, with three pedons exposed in each planting period to a depth of at least 160 cm or to an impenetrable layer, whichever came first. Soil profile site characteristics and morphology were described according to USDA soil survey manual (Soil Survey Staff, 1981). Large bulk soil samples were collected evenly throughout the pedogenic horizons.

Laboratory analyses: The bulk soil samples collected were air-dried and gently crushed in porcelain mortar and passed through a 2 mm sieve. Particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). The soil pH was determined in water using a ratio of 1:2.5 (IITA, 1979). 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 (1998). Potassium and Na in the extract were read on flame analyser, while Ca and Mg were read with atomic absorption spectrophotometer (AAS). Exchangeable Al and H were extracted with 1M KCl and titrated with 0.1M NaOH as described by Anderson and Ingram (1998). Cation exchange capacity of the soil was determined with 1M NH_4OAc (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 as described by Nelson and Sommers (1982). 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 (Bray and Kurtz, 1945). Phosphorus in the extract was estimated colorimetrically in molybdo-phosphoric-blue method as described by Murphy and Riley (1962). Results were subjected to analysis of variance (ANOVA), using GENSTAT V package for statistical analysis.

RESULTS AND DISCUSSION

Morphological properties: The morphological properties (summarised in Table 1) showed that most of the soils were generally deep to very deep. The deepest pedon was more than 165 cm deep, while the shallowest pedon was encountered under 11 year old, followed by the 21 year

Table 1: Morphological properties and classification of pedons under teak plantation in the nimbia forest reserve

Horizon	Depth (cm)	Munsell Colour (Moist)	Mottling	Texture	Structure	Consistence Wet	Moist	Dry	Boundary	Other features
11 year old plantation										
Pedon NF 90 P1 (Humic Dystrustept)										
Ah	0−14	5YR 2.5/2	-	vgcl	1fsbk	sopo	fr	sh	ds	Many fine to medium pores; many fine medium to coarse roots; few hard Fe-oxide nodules; few quartz grains; few ant nests.
AB	14−24	2.5YR 3/4	-	vgcl	1msbk	ssps	fr	sh	ds	Many fine to medium pores; many medium to coarse roots; many fine to medium Fe-oxide nodules; few quartz grains; few ant nests.
BC	24−70	2.5YR 3/4	-	extr. gc	2csbk	sopo	fi	sh	ds	Many fine pores, many fine to few coarse roots; few hard Fe-oxides nodules; few quartz grains; few partially weathered boulders.
C	70−120	2.5YR 3/6	-	extr. gc	1fsg	ssp	fi	sh	-	Few fine pores; few fine roots; partially weathered parent material.
Pedon NF 90 P3 (Oxic Dystrustept)										
Ah	0−10	5YR 3/2	-	vgcl	1msbk	ssp	fi	sh	cs	Many fine pores; many fine medium to coarse roots; few slightly hard Fe-oxide nodules of gravel sizes; few ant and termite nests.
BC	10−50	2.5YR 2.5/4	-	vgc	1fsbk	ssps	fi	sh	ds	Many fine pores; common fine to few coarse roots; many slightly hard Fe-oxide nodules of gravel sizes.
C5	0−140	2.5YR ¾	-	extr. gc	1fsbk	ssps	fi	sh	-	Many fine pores; common fine roots; partially weathered parent material.
21 Years old										
Pedon NF 80 P1(Oxic Dystrustept)										
Ah	0−10	7.5YR 2.5/2	-	vgc	1msbk	ssps	fi	sh	gs	Many few pores; many medium to coarse roots; common slightly hard Fe-oxide nodules; common ant and termite nests.
AB	10−20	2.5YR 3/3	-	vgc	1fsbk	ssps	fi	sh	gs	Many fine pores; many medium to coarse roots, common hard Fe-oxide nodules of gravel sizes; common ant and termite nests.
BC	20−62	2.5YR 2.5/4	-	extr. gc	1msbk	ssps	fi	sh	gs	Few fine pores; many slightly hard Fe-oxide nodules of gravel size; partially weathered parent material.
C6	2−140	2.5YR 2.5/4	-	vgc	1msbk	ssps	fi	sh	-	Few fine pores; common fine to few coarse roots; many hard Fe-oxide nodules of gravel sizes; partially weathered parent material.
Pedon NF 80 P3 (Oxic Dystrustept)										
Ah	0−15	5YR 3/3	-	vgcl	1fsbk	ssps	fi	sh	gs	Many medium pores; many fine to medium roots; many hard Fe-oxide concretions of gravel size; few ant and termite nests.
BA	15−37	2.5YR 3/3	-	vgc	1msbk	ssp	fi	sh	gs	Many fine pores; many medium to coarse roots; few hard Fe-oxide concretions; few termite nests.
Bt	37−75	2.5YR 3/4	-	gc	1msbk	ssps	fi	sh	cs	Few thin clay and Fe-oxide cutans on ped faces; common fine pores; common fine medium to few coarse roots; few fine hard Fe-oxide concretions; few ant and termite nests.
BC	75−120	2.5YR 3/4	-	vgc	1msbk	ssps	fi	sh	-	Many fine pores; many fine and few coarse roots; many hard Fe-oxide concretions of gravel size; partially weathered boulder and parent materials.
31 year old plantation										
Pedon NF 70 P1 (Kanhaplic Haplustult)										
Ah	0−23	7.5YR 2.5/2	-	vgcl	1msbk	ssps	fr	sh	cs	Many medium pores; many fine medium to few coarse roots; few ant nests.
BA	23−44	5YR 3/3	-	gc	2m	sbk	ssps	fi	shc	sMany medium pores; many fine to medium and few coarse roots; common hard Fe-oxide concretions; few ant and termite nests.
Bt1	44−51	5YR 3/3	-	vgc1	msbk	ssps	fi	sh	cs	Many fine pores; many fine and few coarse roots; many fine hard Fe-Mn-oxide concretions; few ant and termite nests.
Bt2	51−81	7.5YR 4/4	-	vgc	2sbk	ssps	fi	sh	cs	Few fine pores; few medium roots; many fine hard Fe-Mn-oxide concretions.
Bt3	81−165	10YR 4/4	-	gc	2msbk	ssps	fi	sh	-	Few fine pores; few medium roots; many fine hard Fe-Mn-oxide concretions of gravel size.
Pedon NF 70 P3 (Kanhaplic Haplustult)										
Ah	019	7.5YR 2.5/2	-	vgcl	1msbk	ssp	fi	sh	cs	Many fine pores; many fine roots; common fine hard Fe-Mn-oxide concretions; many ant nests.
BA	19−45	5YR ¾	-	vgc	2msbk	ssps	fi	sh	ds	Many fine pores; many fine to few roots; many medium to coarse Fe-Mn-oxide concretions; few termite nests.
Bt1	45−77	5YR ¾	-	vgc	2msbk	ssps	fi	sh	cs	Few fine pores; many fine and coarse roots; many coarse hard Fe-Mn-oxide concretions; few ant nests.
Bt2	77−100	7.5YR 4/4	-	vgc	2msbk	ssps	fi	sh	ds	Few fine pores; few fine roots; many hard coarse hard Fe-Mn-oxide concretions.
Bt3	100−145	7.5YR 4/4	-	vgc	2msbk	ssps	fi	sh	-	Few fine pores; few fine roots; many hard coarse Fe-Mn-oxide concretions.

old plantation, where basaltic boulders and petroferric contacts were the sources of depth restriction. Similar depth restriction was observed by Maniyunda (1999), which was ascribed the presences of underlying weathered rock and parent material. There was no marked difference in soil depth that can be ascribed to the age of

Table 1: (Continued)

Horizon	Depth(Cm)	Munsell Colour (Moist)	Mottling	Texture	Structure	Consistence Wet	Moist	Dry	Boundary	Other features
36 year old plantation										
Pedon NF 65 P1 (Typic Haplustult)										
Ah	0−20	2.5YR 2.5/1	-	gscl	2msbk	ssps	fi	sh	cs	Many fine tubular pores; many medium to coarse roots; few ant nests.
BA	20−40	5YR 3/3	-	gc	2msbk	sp	fi	sh	gs	Many medium pores; common fine roots; few Fe-oxide nodules; few fine quartz grains, few termite nests.
Bt1	40−705	YR 4/4	-	gc	2msbk	ssp	fi	h	ds	Few very fine pores; many medium roots; few fine Fe-oxide nodules; few fine quartz grains.
Bt2	70−120	5YR 3/2	-	gc	2msbk	ssp	fi	h	ds	Few fine pores; few Fe-oxide nodules; few quartz grains.
Bt3	120−150	5YR 3/3	-	gc	2msbk	ssp	fi	h	-	Few fine pores; few fine Fe-oxide nodules; few quartz grains.
Pedon NF 65 P3 (Typic Haplustult)										
Ah	0−18	5YR 2.5/3	-	gc	l2msbk	ssp	fi	sh	cs	Many coarse roots; many medium to coarse pores; many medium to coarse roots; few fine quartz grains, few termite nests.
BA	18−36	5YR 3/3	-	vgc	2msbk	ssps	fi	sh	cs	Many medium pores; many medium to few coarse roots; few fine quartz grains.
Bt1	36−62	5YR ¾	-	gc	2msbk	ssp	fi	sh	cs	Few thin clay-Fe-oxide cutans on ped faces; common fine to medium pores, few very fine roots; few quartz grains; few Fe-Mn-oxide concretions.
Bt2	62−112	5YR 4/3	-	gc	2msbk	ssp	fi	sh	ds	Very few thin clay Fe-oxide cutans on ped faces; common fine to coarse roots; few Fe-Mn-oxide concentrations; few quartz grains.
Bt3	112−160	5YR 4/4	-	gc	2msbk	ssp	fi	h	-	Many fine to medium pores; many medium roots; few hard Fe-oxide nodules; few quartz grains; few mica and weathered feldspars.

*1: Symbols used are given in Soil Survey Manual (Soil Survey Staff, 1951, 1981)

the plantation, however pedons under the older plantations were slightly deeper. The difference in depth might suggest to the fact that the younger plantations were established soil units referred to by Barrera (1971) as having minor limitation to plantation establishment. Another possible reason for such non depth difference might be attributed to fact that the trees have not had enough time to effect changes in soil depth as suggested by Ugolini *et al*. (1981).

Surface soils developed under 11 and 21 year plantations were dark reddish brown (5YR2.5/2) to very dark brown (7.5YR2.5/2), while those developed under the older plantations (31 and 36 year old) were reddish black (2.5YR2.5/1) to dark reddish brown (5YR2.5/3). The colour variation was ascribed to higher degree of melanisation under the older plantations. The subsurface horizons under 11 and 21 year old plantations were dark reddish brown (2.5YR3/2 to 2.5YR3/4) colour. The pedons under 31 and 36 year were dark yellowish brown (5YR3/3) to reddish brown (7.5YR4/4). There was an increase in hue (2.5YR to 7.5YR) in both surface and subsurface horizons, under 11 through 36 year old plantations. The increase in pigmentation from yellowish to dark brown which might be as a result of soil aging under the older stands. Similar observation was made by Nayak *et al.* (1999) that soils become redder with increasing age. Cheluviation of the organo-metallic complexes also resulted in braunification, as observed by Schwertmann and Taylor (1989), Schwertmann (1993) that maghemite and haematite are effective pigmenting soil agents.

The texture of the surface horizons under 11 and 21 year old plantations were very gravelly clay loam, while those under 36 year old varied from clay loam to gravelly clay loam, except pedon 1 under 21 and 36 year old were the texture varied from sandy clay loam to sandy clay, indicating a shift in texture from very gravelly clay loam under the younger plantations to gravelly clay textured under the older plantations. The subsurface horizons were gravelly to gravelly clay. This is as result the active pedogenesis taking place in the underlying horizons. The change in texture from clay loam surface to clay subsurface is an indication of active illuviation processes taking place under teak. Arocena and Sanborn (1999), reported that lessivation is a major soil forming processes which resulted into the accumulation of clay in the Bt horizons. Similarly Reitam (2001), observed that after 30 years of forest establishment, sand−size fractions weathered and increased clay accumulation in the thin A-horizon, with silt beneath the transitional AC horizon.

There was a slight structural development from weak fine (under 11 year old) to weak medium and moderate medium subangular blocky structure under 36 year old plantation. The structural development from weak to moderate subangular blocky structure in an indication of alteration of the original soil property by pedogenic processes as floral pedoturbation. Which aided clay lessivation as indicated by clay distribution and the presences of clay cutans in pores and ped surfaces. Similarly increased root activities and organic matter decomposition with aging plantations might have enhanced structural development. Soil consistency under 11 and 21 year old plantations is non sticky to slightly sticky and non plastic to slightly plastic (wet) friable to firm (moist) and soft to slightly hard (dry).Those under 31 and 36 years old plantations are slightly sticky and slightly plastic to plastic (wet), firm (moist) and slightly hard to hard (dry). The increase in consistency might

Table 2: Some physical and chemical properties of pedons under teak plantation in nimbia forest reserve cmol(+)/kg

		%				gk/g			cmol(+)/kg					
Horizon	Depth cm	Sand	Silt	Clay	pH	Org C	Total N	Avail. P mg/kg	TEB	Exch acid	CEC	ECEC	CEC-clay	BS %
11 year old plantation														
Pedon NF 90 P1														
Ah	0−14	36	24	40	6.1	2.70	2.52	12.78	16.32	0.40	28.80	16.71	47.92	57
AB	14−24	28	18	54	5.3	12.86	1.40	9.98	5.44	1.00	18.60	6.43	25.91	29
BC	24−70	16	18	66	5.3	6.43	0.84	7.10	2.73	1.00	18.20	3.73	24.02	15
C	70−120	14	18	68	5.8	4.36	0.84	5.68	4.61	0.40	14.80	4.65	19.41	29
Pedon NF 90 P3														
Ah	0−10	36	20	44	5.9	29.93	2.52	12.10	12.12	0.60	26.80	12.72	36.77	47
BC	10−50	22	20	58	5.0	8.30	0.98	7.10	5.80	0.80	20.0	06.60	29.27	29
C	50−140	24	14	62	5.5	4.98	0.56	11.36	2.43	1.10	14.00	3.44	19.64	17
21 year old plantation														
Pedon NF 80 P1														
Ah	0−10	42	18	40	5.2	33.23	1.96	9.94	14.50	0.40	25.60	13.90	34.79	18
AB	10−20	16	18	66	4.9	12.71	1.26	2.84	2.49	1.20	19.00	3.68	22.00	13
BC	20−62	18	16	66	5.0	6.84	0.98	2.84	1.37	1.00	12.20	2.36	14.82	11
C	62−140	20	18	62	5.0	5.08	0.56	2.84	2.37	0.20	13.00	2.56	18.05	18
Pedon NF 80 P3														
Ah	0−15	44	20	36	6.0	25.94	2.38	11.36	13.78	0.40	56.20	14.19	30.31	25
BA	15−37	14	20	66	5.1	10.79	1.26	5.68	2.20	1.80	13.0	04.00	13.94	17
Bt	37−75	12	18	70	5.1	5.87	0.84	2.84	1.31	0.8	010.0	02.10	11.33	13
BC	75−120	20	16	64	4.7	4.96	0.84	4.26	1.31	1.00	5.20	2.30	5.39	25
31 year old plantation														
Pedon NF 70 P1														
Ah	0−23	34	22	44	6.4	12.89	1.89	19.88	9.71	1.20	26.20	10.90	48.85	37
BA	23−44	20	18	62	5.2	9.16	0.98	8.52	2.81	0.60	18.60	3.41	24.67	15
Bt	144−51	24	18	58	5.1	5.49	0.71	2.84	2.45	1.00	15.60	3.45	23.42	16
Bt	251−81	22	18	60	5.7	5.09	0.71	5.68	1.50	1.00	22.40	2.49	34.14	7
Bt	381−165	16	16	56	5.1	2.65	0.70	11.36	1.40	0.60	13.00	1.78	21.41	9
Pedon NF 70 P3														
Ah	0−12	38	26	36	6.2	22.38	2.94	7.10	15.68	0.60	35.00	16.23	74.18	45
BA	12−45	20	22	58	5.9	7.93	1.12	2.84	4.73	0.40	18.00	5.13	26.25	26
Bt	145-77	16	22	62	5.5	6.51	0.84	2.84	2.87	0.60	16.80	3.47	22.55	17
Bt	277-100	16	20	64	5.1	5.09	0.98	5.68	2.49	0.80	14.80	3.29	20.22	17
Bt	3100-145	20	20	60	6.0	2.65	0.84	2.84	2.31	0.60	15.00	2.91	23.30	15
36 year old plantation														
Pedon NF 65 P1														
Ah	0−20	48	24	28	6.2	16.67	1.12	9.94	8.52	0.60	17.00	9.12	39.65	50
BA	20−40	34	20	46	5.8	9.13	0.98	5.68	4.82	0.80	14.20	5.61	28.84	34
Bt	140−70	34	16	50	5.5	4.88	0.70	5.68	2.96	1.40	16.40	4.35	29.29	18
Bt	270−120	30	16	54	5.2	4.27	0.70	4.26	2.23	4.20	13.80	6.43	22.72	16
Bt	3120−150	32	18	50	5.4	3.05	0.70	5.68	1.61	2.80	12.40	4.40	22.59	13
Pedon NF 65 P3														
Ah	0−18	36	24	40	5.9	14.55	1.26	9.94	8.52	0.60	20.30	9.12	37.64	42
BA	18−36	22	18	60	5.0	8.71	1.26	5.68	2.71	2.40	21.40	5.11	30.38	13
Bt	136−62	20	20	60	5.1	7.88	0.98	9.94	2.64	2.80	18.60	5.44	26.33	14
Bt	262−112	22	20	58	5.3	5.49	0.56	5.68	2.85	2.40	17.60	5.30	26.96	17
Bt	3112−160	34	16	50	5.1	3.05	0.84	4.26	3.11	2.40	18.00	5.50	33.76	17

ascribe to clay lessivation with aging plantation as evidenced by clay cutans. Horizonation however appear subtle as the B horizons are generally clayey in texture and structurally moderate medium sub angular blocky, thus making it difficult to accord horizon differentiations to aging plantations.

Physico-chemical properties: A perusal of the data in Table 2 revealed that the mean sand content for the surface horizons under 11, 21, 31 and 36 year old plantations are as follows 36, 44, 36 and 42%, respectively. The mean values for the corresponding subsurface horizons are in the order 21, 17, 19 and 29 percent for the respective plantation ages. The values for the underlying horizons, showed a slight decrease in sand content compared to the overlying horizons. The decrease in sand content with increased profile depth is reflective of increased pedogenic processes with soil depth. The mean silt contents of the surface horizons slightly varied for the younger plantations, while those of the older plantations did not varied (24%). Similar trend was obtained with the underlying horizons, where values were the same (18%). The distribution of clay under the various plantation ages did not a pronounced difference, except under the oldest plantation where mean values were lower (54%). Relatively higher mean clay contents were obtained in the subsurface horizons, which increased with increasing profile depth irrespective of plantation age. This is ascribed to increased argilluviation in the subsoil horizons as reported by Birkeland (1974), Ezenwa (1988) and Reitam (2001), that clay translocation was higher under forest trees.

Soil pH (H_2O) mean values for surface horizons under 11, 21, 31 and 36 year old plantations are in the order 6.0, 5.6, 6.3 and 6.1, these values slightly varied with plantation age. This non significant change in surface pH might be ascribed to the near similar exchangeable cations in the surface biomass, which slightly differ in acid strength (Rhoades and Binkley, 1995). Minor changes in pH of surface soils under older plantations were also observed by Shukla (2009). Salifu and Meyer (1998), reported high pH values under teak, which was attributed to higher Ca content and teak's ability to act as cation pump. High surface nutrient contents was also reported by Owusu-Bennoah *et al.* (2000), which was ascribed to the ion - pump effects of vegetation. For the subsurface horizons, pH values slightly decreased with soil depth (Table 2), depicting decreased organic matter content, basic cation uptake and leaching. Bhojuaid and Timmer (1998) also reported a decrease subsurface pH under *Prosopis juliflora.* The mean organic carbon values for the Ah horizons are generally high (28.5 to 30.0 g/kg) under the younger plantations, and was twice lower (16 to 18 g/kg) under the older plantations. Similar trend was also observed in the underlying horizons, where values were lower under the older plantations. The higher organic C values obtained in the surface horizons is as a result of increased organic matter inputs and its decomposition as observed by Groenendijk *et al.* (2002), while the lower organic C values in the underlying horizons might be attributed to decreased faunal activities with soil depth as suggested by Browaldh (1995). The lower organic C values obtained under the older plantations might be due to lower litter accumulation after canopy closure, as translocation of dry matter is directed to the bole and lower rates of mineralization a view expressed by Okoro *et al.* (1999) and Nwoboshi (2000). Similarly Quesada *et al.* (2010) corroborated that soil C and N decreased along a gradient of soil age and evolution. The mean values of total N in the surface horizons under 11, 21 and 31 year old plantations were not different, except under the oldest plantation where the mean value was lower (1.19 g/kg). The same trend was observed in the underlying horizons, where the lowest mean value (0.84 g/kg) was obtained under the oldest stand. The decrease in total N with stand age might be as a result of the combined effects of an efficient nitrate uptake by the trees and an enhanced N mineralization a view expressed by Browaldh (1995). He reported decreased NO_3^- and NH_4^+ - N along with enhanced N mineralization as trees aged. Braise *et al.* (1995) observed that NO_3^- content abruptly decreased between the ages of 27 and 47 years, which was ascribed to a decline in litter elemental composition with aging plantation. The mean available phosphorus content varied between 9.94 to 13.49 mg/kg for Ah horizons under the respective plantation ages, however slightly lower P content (9.94 mg/kg) was obtained under the oldest plantation. This might be attributed to higher nutrient utilization as corroborated by Aluko (2001) that trees depended on P for biomass production and teak immobilizes P, thus depleting soil available P with aging plantation. Braise *et al.* (1995), observed that available P linearly decreased with plantation age. The underlying horizons recorded lower available P values which generally decreased with profile depth, a trend obtained with organic C (Table 2). This observation was also confirmed by Samndi (2006), that available P significantly correlated with organic C. The mean values of Total Exchangeable Bases (TEB) in the surface horizons ranged from 8.52 to 14.22 cmol/kg for the respective plantation ages. Mean value was ho wever lower (8.52 cmol(+)/kg) under the oldest plantation. This might be attributed to high nutrient utilization and immobilization by teak according to Nwoboshi (1984). For the underlying horizons, values also decreased with increased soil depth irrespective of plantation age. This decrease in TEB with soil depth is attributed to the relationship that exists between organic C and exchangeable bases. Samndi (2006) observed a highly significant ($r = 0.5372$; $p<0.01$) relationship between TEB and organic C. The exchangeable acidity (Al and H) mean values are generally low (<1.0 cmol(+)/kg) in the surface horizons and ranged between 0.40 to 0.90 cmol/kg. For the underlying horizons, mean values ranged from 0.70 to 2.40 cmol/kg, with higher mean value of 2.40 cmol/kg obtained under the oldest plantation, this is expected as the older plantations have higher nutrient utilization, thus depleting the soil exchangeable bases. This observation was substantiated by Braise *et al.* (1995) that exchangeable acidity linearly increased with plantation age. Cation Exchange Capacity (CEC) for surface horizons under the respective plantation ages, indicated that mean value was lowest (18.5 cmol+kg) under the oldest stand. This is as a result of the fact that low organic matter content was obtained under the older stand as dry matter production in old trees are directed to the boles with very little portion allocated to the leaves (Ashesh and Ramarkrishnan, 1987). Samndi (2006) reported a significant correlation between CEC and organic C in surface horizons under plantation trees. The profile distribution of CEC indicated a decrease with increased soil depth, a pattern similar to the distribution of TEB and organic C. The Effective Cation Exchange Capacity (ECEC) in the surface horizons followed a similar pattern to that of the CEC, with the lowest mean value (9.12 cmol(+)/kg) obtained under the oldest plantation. The lower surface soil ECEC is an assertion of high utilization of exchangeable cations by older trees, resulting in increased kaolinitic content (Norfleet and Smith, 1989) with weathering. Braise *et al.* (1995) made similar observation that ECEC decreased linearly with stand age in forest floor of boreal species north western Quebec. The ECEC values for the underlying horizons were lower than the surface horizons and decreased with profile depth. The CEC - clay mean values ranged from 32.55 to

62.52 cmol(+)/kg for surface horizons, while for the underlying horizons values were lower, irregular distribution and ranged between 14.26 and 27.61 cmol(+)/kg, for both horizons. The base saturation (CEC-NH_4OAc) in the surface soils was generally low and ranged between 22 to 52%. Mean values were slightly higher under the youngest plantation, followed by those of 31 and 36 year old plantations. Similar distribution pattern was observed in the underlying horizons, though values were slightly lower and decreased with profile depth, reflective of organic C distribution.

Soil classification: The soils of the study area were classified using the USDA Soil Taxonomy (Soil Survey Staff, 1975, 1999), FAO/UNESCO Soil Map of the World Legend (FAO/UNESCO, 1974, 1988) and World Reference Base (FAO/ISSS, 1998). The differentiating properties used for the classification included some morphological, physical and chemical properties.

The annual rainfall in the study area (Nimbia Forest Reserve) is about 1260 mm, reflective of the Southern Guinea Savanna zone of Nigeria. The rainy months are from May through September. Sometimes rain starts in April and ends in October, resulting into seven months of rainy periods. This fact implies that the soil is moist for more than 180 cumulative days and is dry for 90 or more cumulative days (Soil Survey Staff, 1975, 1999). This implies that the rainy periods are more than 180 days and the pedons are well drained, thus suggesting an Ustic moisture regime. The mean annual soil temperature of the study area is 22ºC. The mean summer (23ºC) and winter (21ºC) soil temperatures do not differ by up to 6ºC (2ºC) at a depth of 50 cm. This temperature characteristic implies that the prevailing soil temperature regime is Isohyperthermic.

USDA soil taxonomy system: All the pedons under the various plantation ages have umbric epipedons. The pedons under the younger plantations (11 and 21 year old) have cambic subsurface horizons, while those under the older plantations (31 and 36 year old) have argillic horizons. The older pedons have less than 50% base saturation (by NH_4OAc) and less than 90% (ECEC). Considering these properties with respect to the criteria of USDA Soil Taxonomy (Soil Survey Staff, 1975, 1998, 1999), soils under 11 and 21 year old plantations are classified into the order Inceptisols, and those under 31 and 36 year old are classified into the order Ultisols. At the suborder levels, the pedons are classified as Ustepts and Ustults, as a result of their Ustic moisture regimes. Considering other classification criteria, such as the presences or absence of duripan, the soils were further classified at the great group levels.

Pedons under 11 and 21 year old plantations have a base saturation (by NH_4 OAc) less 60% in all horizons at a depth between 25 and 75 cm from the soil surface, thus classifying the pedons into the great group Dystrustepts. Pedons under 31 and 36 years old plantations, have epipedons that have colour value moist of 3 or less, a thin or moderately thick zone of maximum clay content in the argillic horizon and do not have a kandic horizon. The pedons also do not have plinthite that forms a continuous phase or constitute more than half the matrix in any sub horizons within 150 cm of the mineral soil surface, thus qualify the pedons in the great group Haplustults.

At the subgroup level, pedons under 11 and 21 year old plantations are classified as Oxic Dystrustept, because these pedons have 50% or more of the soil volume between a depth of 25 and 100 cm from the mineral soil surface and have a CEC (1M NH_4OAc) of less than 24 cmol(+)/kg clay. Pedon NF90 P1 is however, classified as Humic Dystrustept, because it has an umbric epipedon (Soil Survey Staff, 1999). The pedons under 31 and 36 year old plantations are moderately deep to very deep and have argillic horizons with a texture finer than loamy fine sand in some parts of the argillic horizon and also have no lithic contact within 50 cm of the soil surface. However, pedon 31 year old plantation, have CEC (1M NH_4OAc) less than 24 cmol(+)/kg clay in 50% or more in the upper 100 cm of its argillic horizon, and are classified as Kanhaplic Haplustults. Pedons under 36 year old plantation however have more than 24 cmol(+)/kg clay in most part of their argillic horizons and are therefore classified as Typic Haplustults.

Classification according to FAO/UNESCO soil legend: Soils under the various plantations ages have structures that are both not massive and hard or very hard when dry. Their base saturation (by NH_4OAc) are generally less than 50%, with organic content greater than 0.6 percent,thus classifying them as having umbric epipedons. The subsurface horizons under 11 and 21 year old plantations have a texture that is sandy loam or finer with at least 8% clay in earth fraction, with CEC - clay more than 16 cmol(+)/kg, thus classifying these pedons as having cambic B horizons. The pedons under 31 and 36 year old plantations have higher subsoil clay content than the overlying surface horizons. Pedon NF65 P3 have clay-CEC more than 24 cmol(+)/kg and a base saturation (by NH_4 OAc) less than 50%, while the other pedons, have clay-CEC less than 24 cmol(+)/kg, base saturation (by NH_4OAc) less than 50% in at least some parts of the B horizons within 125 cm of the surface and classifying these pedons as having argic B horizons.

At the unit level, pedons under 11 and 21 year old plantation are classified as Cambisol. These pedons have cambic B horizons, with less than 50% base saturation, thus these pedons were further classified at the subunit level as Humic Cambisol. These pedons have umbric A horizons, clay-CEC greater than 16 cmol/kg, ECEC less than 12 cmol(+)/kg and silt/clay ratio greater than 0.20.

Table 3: Summary of soil classification (USDA, FAO/UNESCO and WRB systems)

Pedon	USD	AFAO/UNESCO	WRB
11 year old plantation			
NF 90 P1	Humic Dystrustept	Humic Cambisols	Chromic Umbrisols
NF 90 P3	Oxic Dystrustept	Humic Cambisols	Chromic Umbrisols
21 year old plantation			
NF 80 P1	Oxic Dystrustept	Humic Cambisols	Chromic Umbrisols
NF 80 P3	Oxic Dystrustept	Humic Cambisols	Chromic Umbrisols
31 year old plantation			
NF 70 P2	Kanhaplic Haplustult	Humic Acrisols	Umbrihumic Acrisols
NF 70 P3	Kanhaplic Haplustult	Humic Acrisols	Umbrihumic Acrisols Acrisols
36 year old plantation			
NF 65 P_2	Typic Haplustults	Chromic Luvisols	Chromic Luvisols
NF 65 P_3	Typic Haplustults	Chromic Luvisols	Chromic Luvisols

For soils under 31 and 36 year old plantations, pedon NF65P3 is classified into the unit as Luvisols, because its CEC-clay is more than 24 cmol(+)/kg in the argic horizons, while the other pedons are classified at the unit level as Acrisols. These pedons have strong brown to red B horizons (hue of 7.5YR and chroma moist of 4 or a hue redder than 7.5YR) and umbric epipedons which are strongly humic and lacking plinthite within 125 cm of the surface. These soils are therefore classified according to FAO /UNESCO Soil legend (1974, 1988) in the subunit and Humic Acrisols and Chromic Luvisols

Classification according to world reference base for soil resources: Using the World Reference Base for Soil resources, soils under 11and 21 year old plantations are classified as Umbrisols, because they have an umbric epipedons in addition to having cambic B horizons. For soils under 31 year old plantation are classified as Acrisols, as they have base saturation (1M NH_4OAc) less than 50% between 25 and 100 cm depth, have argic horizons and clay-CEC less than 24 cmol(+)/kg. Pedon NF65P3, have argic horizon with more than 24 cmol(+)/kg clay in most parts of its argic horizon and is therefore classified as Luvisols.

At the lower level of classification, all the pedons under the younger plantations are classified as umbrisols. This is because apart from having a cambic B horizons, they have CEC (by 1M NH_4OAc), more than 16 cmol+kg and the sum of exchangeable bases plus exchangeable acidity (1M KCl) of less than 12 cmol(+)/kg clay in most parts of the profiles. Soils under 36 year old plantations are classified Chromic, because they all have B horizons in which the hue is redder than 7.5YR. For the soil under 31 year old plantation are classified as Umbrihumic as having organic carbon more than 0.6% and a base saturation (by NH_4OAc) less than 50%. The summary of the classification is given in Table 3.

CONCLUSION

Results from the study on the roles of *Tectona grandis* in pedogenic processes, showed that the major pedogenic processes under trees were braunification, mineralization and lessivation. Floral pedoturbation contributed to clay illuviation, which resulted in the formation of clay firms on ped surfaces and Bt horizons. There was a slight shift in soil texture from gravelly clay loam to gravelly clay horizons under 11 through 36 year old plantations. Soil structure varied from weak fine to medium moderate subangular blocky structure with aging plantations. The soils were strongly to moderately acid with pH values between 5.6 and 6.3. Organic C and total contents were significantly higher in the surface horizons and slightly varied with both soil depth and plantation age. Available P linearly decreased as plantation ages, an indication of soil development. Total Exchangeable Bases (TEB) contents generally decreased with both soil depth and plantation ages. The soils underneath the plantation were classified as follows, those under 11 and 21 year old plantations were classified in accordance to the USDA Soil Taxonomy as Humic Dystrustept and Oxic Dystrustept. The soils under 31 and 36 year old plantations were classified as Kanhaplic Haplustults, and Typic Haplustults, Applying the FOA/UNESCO system of classification, soils under 11 and 21 year old plantations were classified as Humic Cambisols, while those under 31 and 36 year old plantations were classified as Humic Acrisols and Chromic Luvisols. The soils were further classified using the World Reference Base for Soil Resources. The soils under 11 and 21 year old plantations were classified as Chromic Umbrisols and those under 31 and 36 year old plantations were classified as Umbrihumic Acrisols and Chromic Luvisols.

REFERENCES

Aluko, A.P. and J.A. Fagbernro, 2001. The role of tree species on land use systems in organic matter and nutrient availability in degraded Ultisols of Onne, south-south-Nigeria. Paper Presented at 26th Annual Conference of Soil Science Socity of Nigeria, Ibadan.

Anderson, J.S. and J.I.S. Ingram, 1998. Tropical Soil Biology and Fertility: A Handbook of Methods. 2nd Edn., Information Press, U.K., pp: 221.

Arocena, J.M. and P. Sanborn, 1999. Mineralogy and genesis of selected soils and their implications for forest management in central and north eastern British Columbia. Can. J. Soil Sci., 79: 571-592.

Armson, K.A., 1977. Forest Soils Properties and Processes. University of Toronto Press, Toronto and Buffalo, pp: 31.

Ashesh,K.D.andP.S.Ramarkrishnan, 1987. Above-ground biomass and nutrient contents in an age series khasi pine *Pinus kesiya*. Forest Ecol. Mgt., 18: 61-72.

Barrera, A., 1971. The Use of Soil Survey in Assessing Sites for Forestry Potential Area of the Northern States of Nigeria. Techn. Report S. Savanna Forestry Research Station Nigeria.

Bhojuaid, P.P. and V.R. Timmer, 1998. Soil dynamics in an age sequence of *Prosopis duliflora* planted for sodic restoration in India. Forest Ecol. Manage., 106: 181-193.

Birkeland, P.W., 1974. Pedology, Weathering and Geomorphological Research. Oxford University Press, New York.

Blevins, R.L., N. Holowaychuck and L.P. Wilding, 1970. Micromorphology of soil fibric at the tree-root-soil interface. Soil Sci. Am. Proc., 34: 460-465.

Braise, S., C.C. Bergeron and D. Pare, 1995. Changes in nutrient availability and forest floor characteristics in relation to stand age and forest composition in the Northwestern Quebec. Forest Ecol. Manage., 76: 181-189.

Bray, R.H. and L.T. Kurtz, 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci., 59: 39-45.

Bremner, J.M., 1982. Inorganic Nitrogen. In: Page, A.L., R.H. Miller and D.R. Keeney, (Eds.), Methods of Soil Analysis. Part 2. 2nd Edn., Amer. Soc. of Agron, Madison, pp: 595-624.

Browaldh, M., 1995. The influence of trees on nitrogen dynamics in an agrisilvicultural system in Sweden. Agroforest. Syst., 30(3): 301-313.

Certini, G., Y. Maria, S. Fernandez, C. Giuseppe and F.C. Ugolini, 2001. The contrasting effect of broom and pine on pedogenic processes in volcanic soils (Mt Etna Italy). Geoderma, 102: 239-254.

Chapman, H.D., 1965. Cation Exchange Capacity. In: Black, C.A., (Ed.), Methods of Soil analysis. Part2. Agron. No. 9 ASA Madison Wisconcin, USA, pp: 891-901.

D'Hoore, J.L., 1964. Soil Map of Africa. Scale 1:500,000 Explaratory Monograph. C.C.T. Lagos, pp: 205.

Duning, X., R.H. Rust and J.R. Crum,1986. Numerical classification of forested soils in the high mountain region of south western China. Soil Sci. 141(2): 127-137.

Ezenwa, M.I.S., 1988. Classification of soils as related to the growth of plantation tree species in the savannas. PhD Thesis, Unpublished. Ahmadu Bello University, Zaria, pp: 314.

Folster, H., N. Mosherif and A.G. Ojanuga, 1971. Ferrallitic pedogesis on metamorphic rock south-western Nigeria. Pedologic XXI, 11(1): 95-124.

FAO/ISSS, 1998. World Reference base for soil Resources. Food and Agriculture Organisation of the United Nation. 84 World Soil resources reports.

FAO/UNESCO, 1974. Soil Map of the World legend. UNESCO, Paris.

FAO/UNESCO, 1988. Soil Map of the World Legend. Revised Edn., Paris.

Gee, G.W. and Y.N. Bauder, 1986. Particle Size Analysis. In: Klute, A., (Ed.), Methods of Soil Analysis. Part 1 Agron. Madison. W.I. USA, pp: 381-411.

Groenendijk, F.M., L.M. Condron and W.C. Rijkse, 2002. Effects of Afforestation on Organic Carbon, Nitrogen and sulphur Concentrations. New Zealand Hill, New Zealand.

Howard, W.J., 1963. Jemma'a Nimbia Forest Reserve. Report on vegetation and site types. pp: 14.

IITA., 1979. Selected methods for soil and plant analysis international institute of tropical agriculture. Manual series No., 1: 21-35.

Junge, B. and A. Skowronek, 2007. Genesis, properties, classification and assessment of soils in central Benin W. Africa. Geoderma, 139: 357-370.

Maniyunda, L.M., 1999. Pedogenesis on loess and basement complex rocks at funtua nigeria. M Sc Thesis, Ahmadu Bello University, Zaria, (Unpublished), pp: 107.

Murphy, J. and J. P. Riley, 1962. A modified single solution method for the determination of phosphate in natural water. Anal. Chem. Act., 27: 31-36.

Nayak, D.C., S.K.D. Dipak and S. Chatterjee, 1999. Studies on pedogenesis in a soil chronoequence in west Bengal. J. Ind. Soc. Soil Sci., 47(2): 322-328.

Nelson, D.W. and L.E. Sommers, 1982. Organic Carbon. In: Page A.L., (Ed.), Methods of Soil Analysis. Part 2. Agron. Mongr. 9 ASA. Madison, pp: 570-571.

Norfleet, M.L. and B.R. Smith, 1989. Weathering and mineralogical classification of selected soils in the Blue Ridge Mountains of South Carolina. Soil Sci. Soc. Am. J., 53: 1771-1778.

Nwoboshi, L.C., 1984. Growth and nutrient requirements in a teak plantation age series in Nigeria. II Nutrient accumulation and minimum annual requirements. Sci., 30(1): 35-40.

Nwoboshi, L.C., 2000. The Nutrient Factor in Sustainable Forestry. Ibadan Univ. Press, Ibadan, pp: 132.

Ohta, S., 1990. Initial Soil changes associated with afforestation with *Acacia auriculiforms* and *Pinu kesiye* on denuded glassland of the Pantabangan area Central Luzon, the Philipines *Soil* Sci. Plant Nutr., 36(4): 633-643.

Okoli Paul, S.O. and G.F. Wilson, 1982. Role of fallow shrubs and trees in soil conservation and productivity. Proceeding on 10th Annual Conference of Soil Science Society, Nigeria.

Okoro, S.P., A. Aighewi and C.O. Osagie, 1999. Effects of selected monoculture plantation species on humid tropical soils of southern Nigeria. Nig. J. Forest., 29(2-3): 73-79.

Owusu-Bennoah, E.,T.W. Awadzi, E. Boateng, L. Krogh, H. Breuning-Madson and O.K. Borggaard, 2000. Soil properties of a toposequence in the moist semi-deciduous forest of Ghana West Africa. J. App. Eco., 1: 1-10.

Quesada, C.A., J. Lloyd and M. Schwartz, 2010. Variations in chemical and physical properties of forest soils in relation to their genesis. Biog. Sci., 7: 1515-1541.

Reitam, L., 2001. Changes in the texture and exchange properties of skeletal quarry detritus under forest during thirty years. Proc. Acad. Sci. Biol. Ecol., 50: 15-13.

Rhodes, J.D., 1982. Cation Exchange Capacity. In: Page A.L., R.H. Miller and D.R. Keeney, (Eds.), Methods of soil Analysis part 2. Chemical and microbiological properties. Agron. No 9, pp: 149-157.

Rhoades, C. and D. Binkley, 1995. Factors influencing decline in soil pH in Hawaiian Eucalyptus and Albizia plantations. Forest Eco. Mgt., 80: 47-56.

Russell, A.E., J.W. Raich, O. J. Valverde-Barrentes and R.F. Fisher, 2007. Tree Species effects on soil properties in Experimental Plantation in Tropical Moist Forest. Soil Sci. Am., 71(4): pp.

Salifu, K.F. and W.L. Meyer, 1998. Physico-chemical properties of soils associated with logged forest and areas converted to Teak (*Tectona grandis*) in Ghana. Common Wealth For. Rev., 77(2): 91-99.

Samndi, A.M., 2006. An Evaluation of Soil Properties and Development under Teak (Tectona grandis) Plantation of Various ages in Southern Guinea Savanna of Nigeria. Unpublish Ph.D. Thesis, Dissertatation, Ahmadu Bello Univer. Zaria, Nigeria.

Schulze, D.G., J.L. Nagel, G.E. Vanscoyoc, T.L. Henderson and M.F. Baumgardner, 1993. Significance of Organic Matter in Determining Soil Colour. SSSA Spec. Publ. 31. SSSA Madison W.I.

Schwertmann, U. and R.M. Taylor, 1989. Iron Oxides. In: Dixon, J.B. and S.B. Weed, (Eds.), Minerals in Soil Environment. Am. Soc. Agron. Madison Wisconsin, USA, pp: 379-438.

Schwertmann, U., 1993. Relations between Iron Oxides Soil Colour and Soil Formation. In: Bigham, J.M. and E.J. Ciolkosz, (Eds.), Soil Colour. SSSA Spec. Publ. 31 SSSA, Madison, W.I.

Shukla, P.K., 2009. Nutrient Dynamics of teak plantations and their impact on soil productivity. A case study from India. XIII Wold Forest Congress. Buenos Aires Argentina 18-23 October 2009.

Simonson, R.W., 1959. Outline of a generalized theory of soil changes. Soil Sci. Soc. Am. Proc., 23: 152-156.

Soil Survey Staff, 1951. Soil Survey Manual. Soil Conservation Service. USDA. US Govt Printing Office. USA, Washington DC, pp: 139-140.

Soil Survey staff, 1975. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Survey. Handbook 436. Soil conservation service USDA. Washington DC, pp: 227-349.

Soil Survey Staff, 1981. Examination and Description of Soils in the Field. In Soil Survey Manual. USDA Agric. Handbook 18. US Govt Printing Office, Washington DC.

Soil Survey Staff, 1998. Keys to Soil Taxonomy USDA. Natural Resources Conservation Services. Eighth End, pp: 336.

Soil Survey Staff, 1999. Keys to Soil Taxonomy. A Basic System of Soil Making and Interpreting Soil Surveys. 2nd Edn., USDA Natural Resources Conservation Services, pp: 869.

Stevenson, F.J., 1982. Humus Chemistry, Genesis Composition Reactions. John Wisley, New York, pp: 443.

Ugolini, C.F., H.R., Reanier, H.G. Rau and I.J. Hedges, 1981. Pedological, Isotopic and geochemical investigations of the soils at the boreal forest and Alpine tundra transition in Northern Alaska. Soil Sci., 131(6): 359-374.

Wilde, S.A., 1957. Forest Soils. Their Properties and Relation to Silviculture. The Ronald Press Comp. New York, pp: 102-104.

William, L.P., 1979. Properties and Management of Forest Soils. John Wiley and sons, New York Chichester, Brisbane Toronto III, pp: 500.