Colloquia SSSN 44 (2020) 270-276

Colloquia Series

Available online at www.publishingrealtime.com

Publishing Real Time

Colloquia SSSN 44 (2020)

Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Effects of coffee and rubber plantations on the physico-chemical properties of an Ultisol in Umudike, Southeastern Nigeria.

[1] Nnaji, G. U., [1] Agubuche, C. M. and [2]Omeke, J. O.

[1]Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

[2]National Agricultural Extension and Research Liason Services, Ahmadu Bello University, P. M. B. 1067, Zaria, Nigeria

Abstract

The effects of coffee and rubber plantations land use types on the physico-chemical properties of an Ultisol were studied in Umudike, Ikwuano Local Government Area of Abia state, Southeastern Nigeria. The experimental design used for the study was 4 x 3 factorial in Randomized Complete Block Design. The two factors assessed were Land Use Type (LUT) and Soil Depth. The LUT were at Four levels: rubber plantation, coffee plantation, natural forest and arable cropping while the soil depth was at three levels- 0 -20cm, 20-40cm, and 40-60cm depths. The natural forest and arable cropping served as controls. Data generated were subjected to analysis of variance and means were separated for significant differences using F-LSD. Results showed that the textural class of soil under Rubber Plantation was sandy clay loam at the surface and sandy clay at the sub-surface; whereas the texture of soils of other land use types were sandy loam at both surface and subsurface. The bulk density of soils increased with depth, whereas total porosity as well as the saturated hydraulic conductivity decreased with depth. Highest (P>0.05) bulk density of 1.9 g cm^{-3} was recorded for soil of rubber plantation while the least value, 1.3 g cm^{-3} was obtained under natural forest soil. Natural forest had a moderate acidic reaction whereas soils of other land uses were strongly acidic. Natural forest had the highest (P> 0.05) pH of 6.30 at 0-20cm depth. There was decrease in pH with increase in soil depth. Available phosphorus across all land use types was low. Total Nitrogen ranged from 0.18 to 0.05g kg^{-1}, with natural forest having the highest value and cultivated land having the lowest. Organic matter content of the soils ranged from 11.20 to 20.00 g kg^{-1}, this was rated low to moderate. Total nitrogen and organic matter decreased (P>0.05) with depth. The organic matter increased (P>0.05) in this order- Natural forest > coffee plantation > rubber plantation >arable cropping LUTs at all sampling depths. Although soils of rubber and coffee plantations were better than soils of the arable cropping in the fertility indices assessed, the two plantation land use types were inadequate in conserving the soils relative to the natural forest.

Keywords: Rubber, Coffee, Plantation, Land use type, Soil physico-chemical properties.

Corresponding Author's E-mail Address: goduche66@gmail.com: Phone: +2348037427681
https://doi.org/10.36265/colsssn.2020.4439

Peer-review under responsibility of 44th SSSN Conference LoC2020.

1.0. Introduction

Rubber and Coffee trees are commercial trees grown in plantations around the world with the capacity to produce about 50 million pounds of natural rubber and coffee by the year 2020 (Venkatachalam, 2013; Ricketts, 2004). According to the FAO (2010), natural rubber plant has a long history of being cultivated for commercial uses, and is important in the socio-economic life of many tropical countries like Nigeria. Natural rubber (NR) is of strategic importance because it cannot be replaced by synthetic alternatives in many of its most significant applications owing to its unique properties such as resilience, elasticity, abrasion and impact resistance, efficient heat dispersion and malleability at low temperatures (Van Beilen and Poirier, 2007). Africa produces 5% of global natural rubber, with Nigeria, Liberia and Cote d'Ivoire as the largest producers (WRM, 2008). In the early 1990s, there was increasing demand for natural rubber worldwide and the government of Nigeria realizing the potential of natural rubber cultivation to economically empower many small-scale farmers and alleviate poverty in rural communities, entered into an agreement with the IDA/World Bank to assist out growers in establishing natural rubber plantations (Delarue, 2009).

Also, Coffee is one of the most valuable agricultural export products from developing nations, and this industry is estimated to employ over 25 million people worldwide (FAO, 2010). It is an important cash crop and was widely mono-cultured in the tropical and subtropical regions of Nigeria, with a total planting area of approximately 50,000 hectares (Ayoola, 2015). Coffee has been popularly used in the food and beverage industry because of its multiple pharmacological effects, such as reducing the risk of colorectal cancer as well as cardiovascular disease (Li *et al,* 2013). In Nigeria, the suitable regions for coffee planting are very limited, thus continuous monoculture coffee-growing regimes are commonly practiced to meet the increasing market demands. However, long-term monoculture with inadequate soil conservation, cultural and management practices often leads to soil degradation, poor growth, low yield and serious soil-borne disease in coffee plant (Li *et al.,* 2016). This results in severe economic losses and hinder sustainable development of the coffee industry in Nigeria.

Land-use systems characterized by perennial crops, which provide litter and shading to the soil especially during the maturity phase, may improve stocks of nutrients and other soil fertility parameters to levels capable of sustaining crop productivity (Beer *et al.,* 1998). Thus, while some studies (Duguma *et al.,* 2001; Wall and Hytönen, 2005) have reported improvements in soil organic carbon and fertility under various tree crops and forest plantations, others (Ekanade *et al.,* 1991; Ogunkunle and Eghaghara, 1992; Duah-Yentumi *et al.,* 1998) have reported declines in soil fertility following forest conversion to plantations. Other reports (Kotto-Same *et al.,* 1997; Kauffman *et al.,* 1998) have also indicated that soil carbon pools remain approximately constant during most land conversion practices in the tropics.

In southeastern Nigeria, there is paucity of information on the variations in soil physical and chemical properties under rubber and coffee plantation land use types. As a consequence, the dynamics of soil physico-chemical properties under perennial stands like rubber and coffee plantations are still not well understood. Studies are needed to understand the trends, magnitudes, nature and rates of soil quality changes when soil is converted from forest to perennial crop plantations.

The objective of this study are to determine selected physical and chemical properties of soils planted with coffee and rubber and compare them with that of natural forest and continuously cultivated arable crop land use types.

2.0. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Umudike in Ikwuano local government area, Abia State. Ikwuano local government lies between latitudes 5°27′ and 5°29′ N and Longitudes 7°25′ and 7°35′ E (Chukwu, 2013). Ikwuano local government area has a total landmass of 198 km^2. Umudike, Abia State is located within the tropical rainforest belt. The climate is typically hot humid tropical with a mean annual rainfall from about 3000mm along the coast to 2000mm in the hinterlands (Nigeria Meteorological Agency, 2015). The mean annual temperature is generally uniform, ranging from 26° C to 28° C (Nigeria Meteorological Agency, 2015). The climate is divided into the wet season (April to October) and the dry season (November to March). The rainy season is characterized by bimodal rainfall pattern with peaks occurring in July and September and short dry spell of about three weeks between the peaks known as the August break (Nigeria Meteorological Agency, 2015)). Relative humidity varies between 75 and 90 %.

Umudike lies within the rain forest area of the state which has been almost completely replaced by secondary forest of predominantly rubber plantation and oil palm trees of various densities of coverage inter-mixed with tall grasses, herbaceous and woody shrubs such as *Chromolaena odorata* (Siam weed). The soil is characterized by differences in topography due to upland and inland valleys within the rural landscape. Coastal plain sands is the dominant parent material in the area (Chukwu *et al.,* 2014). The area has potential for different land use options ranging from arable crop and tree crop production to forestry, animal husbandry and fishery. The predominant land use in the area as in most of the South-east is the cropping-bush fallow-cropping closed system and the major crops grown are rice, cocoa, yams, cassava, maize and vegetables. The main land-use type is arable crop production. The cropping systems are either tree-crop based or root-crop based, with the latter predominating.

2.2. Field methods

Through reconnaissance visits to Umudike communities and use of available soil and geologic maps of Umudike, fields within the same topographic conditions and soils formed from same parent materials but differed in their land use types (LUTs) were identified and used for this study. The experimental design used for the study was 4 x 3 factorial in Randomized Complete Block Design. The two factors assessed were Land Use Types (LUT) and Soil Depth. The LUT were at Four levels: rubber plantation, coffee plantation, natural forest and continuously cultivated arable cropping (cassava+maize mixed cropping) while the soil depth was at three levels- 0-20cm, 20-40cm, and 40-60cm depths. Fields under each of the LUTs were marked. Three sampling points were selected in the field under each of the LUTs. Soil samples were collected at three depths, 0-20cm, 20-40cm and 40 – 60 cm depths. At each depth, both disturbed auger samples and undisturbed core samples were collected. This amounted to 72 soil samples. The samples were taken to the laboratory; their physical and chemical properties were determined as follows:

2.3. Physical properties

Particle size distribution was determined using the Bouyoucos hydrometer method as described by Gee and Or (2002). Bulk Density was determined by the core method as described by Blake (2003). Total porosity was calculated from particle and bulk density as follows:

$$f = \left(1 - \frac{\ell b}{\ell p}\right)$$

where,

f = total porosity
ℓb = Bulk density
ℓp = particle density

Saturated Hydraulic Conductivity (K_{sat}) was determined using the constant head permeameter method as described by Young (2001), Ksat was calculated using the equation:

$$K_{sat} = \frac{QL}{\Delta h A t}$$

Where;

Ksat = saturated hydraulic conductivity
Q = discharge rate
L = length of soil column
Δh = change in hydraulic head
A = the interior cross sectional area of the column
t = the time of flow

2.4. Chemical properties

Soil pH was determined in 1NKCl using a 1: 2.5 soil to salt suspension, and the pH value read with a glass electrode pH meter. Organic carbon was measured by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommer, 1996). Total Nitrogen was determined by the Kjeidahl digestion and distillation method as described by Udo *et al.* (2009). Available phosphorus was determined by the Bray 11 method (Bray and Kurtz, 1954). Exchangeable bases were extracted using 1N ammonium acetate (NH_4OAC). Sodium and potassium were read using flame photometer while Calcium and Magnesium were determined using Ethylene Diamine Tetra-Acetic (EDTA) titration method of Thomas (1982). Exchangeable Acidity and aluminium were determined by the method of Maclean (1982) using 1N KCl as the extracting solution and titrating with 0.05 NaOH. However exchangeable Al^{3+} was obtained by back-titration of the same KCl extract, previously used, after the acidification with a drop of HCl and addition of 40g L^{-1} NaF, with 0.025 mol L^{-1} HCl. Effective Cation Exchange Capacity was calculated by summation of all exchangeable bases (Mg^{2+}, K^+, Na^+, Ca^{2+}) and total exchangeable acidity.

2.5. Statistical Analysis

Descriptive statistics such as means, percentages, tables and coefficient of variation were used to express variation in soils. Also, Data collected were subjected to analysis of variance. Treatment means were separated using Fisher's Least Significant Difference (F-SLD).

3.0. Results and Discussion

3.1. Particle size distribution, bulk density, porosity and hydraulic conductivity

The particle size distribution of the soils studied is shown in Table 1. Sand dominated the other particle sizes, values ranging from 670 to 724 gkg^{-1} were obtained for the soils. Generally, the sand contents decreased with depth while the silt and clay contents increased (P>0.05). However, the silt content under coffee plantation decreased (P>0.05) with depth. The texture of the soils and at various depths was sandy loam except for rubber plantation which was observed to have a sandy clay loam texture at 0-20cm depth and clay loam at the other sub-surface depths. Soils of the different LUTs did not differ in sand, silt and clay contents.

The high sand contents of the soils could be attributed to their being derived from unconsolidated sand deposits formed over coastal plain sand (Asawalam *et al*., 2009; Chukwu, 2013). The sandy loam texture observed in coffee plantation and forest land, corroborated the report of Ufot *et al*. (2016), who reported sandy loam texture for a tree crop plantation and forest land in Alokwa, Imo State. On the contrary, Shepherd *et al.* (2000) observed that changes due to a land use do not show easily for particle size. Soil texture unlike biochemical attributes is an inherent property of the soil that is not easily influenced by land use types (Bernitez *et al.,* 2006). However certain land uses may encourage accelerated clay illuviation due to exposure to rainfall, erosion and leaching. The clay content in rubber plantation were slightly higher probably because erosion and eluviation processes are relatively lower under the LUT. The increase in clay with soil depth may be due to eluviations of this particles down the profile as a result of intense torrential rainfall (Oguike and Onwuka, 2017), argillation of clay, lessivage and sorting of soil materials (Ojanuga, 2003).

Table 1: Particle size distribution of soils under the different land uses and soil

Land use	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{1})	Texture
	0 – 20 cm			
Rubber plantation	670.00	80.00	250.00	Sandy clay loam
Coffee plantation	716.00	112.00	172.00	Sandy loam
Natural Forest	724.00	87.00	189.00	Sandy loam
Cultivated land	710.00	72.00	218.00	Sandy loam
Mean	705.00	87.75	207.25	
%CV	25.10	34.00	40.60	
	20 – 40 cm			
Rubber plantation	590.00	140.00	270.00	Clay loam
Coffee plantation	710.00	109.00	181.00	Sandy loam
Natural Forest	719.00	90.00	191.00	Sandy loam
Cultivated land	699.00	81.00	220.00	Sandy loam
Mean	679.50	105.00	215.50	
%CV	22.05	33.54	40.10	
	40 – 60 cm			
Rubber plantation	600.00	107.00	293.00	Clay loam
Coffee plantation	705.00	101.00	194.00	Sandy loam
Natural Forest	711.00	93.00	196.00	Sandy loam
Cultivated land	695.00	89.00	216.00	Sandy loam
Mean	677.75	97.50	224.75	
%CV	23.96	25.20	31.00	

The bulk density, porosity and saturated hydraulic conductivity of the soils studied are shown in Table 2. At the three depths of 0 – 20, 20 – 40 and 40 – 60 cm, rubber plantation had highest bulk densities, with values ranging from 1.61Mgm^{-3} at 0 – 20 cm to 1.92 Mg m^{-3} at 40 – 60 cm depth. The lowest bulk densities were observed in forest land at the three depths with values ranging from 1.32

Mgm^{-3} at 0 – 20 cm to 1.58 Mgm^{-3}at 40 – 60 cm. With regard to porosity, forest land had the highest porosity at the three depths. Rubber plantation recorded the lowest total porosity which ranged from 28.10 % at 40 – 60 cm to 39.70 % at 0 – 20 cm relative to other land uses. Forest land had the highest saturated hydraulic conductivity with values ranging from 24 to 13cm hr^{-1} at the three depths, while cultivated land had the lowest, with values ranging from 10.20 to 13.20 cm hr^{-1}. Generally, the bulk density of the soils increased with depth, whereas total porosity as well as the saturated hydraulic conductivity decreased with depth (Table 2). There was no significant difference (P>0.05) between the soils of the LUTs in bulk density, porosity and Ks. These observations reflected the influence of organic matter on the parameters. With reduced organic matter content, bulk density increased while total porosity decreased resulting to a reduction in saturated hydraulic conductivity (Baunhardt and Lascano, 1996).The variation in bulk density and total porosity may be attributed to the level of organic matter in the soils (Okolo *et al*., 2013). Therefore, the lowest bulk density and highest total porosity and saturated hydraulic conductivity observed under natural forest may be as a result of the higher organic matter content of the natural forest. This concurred with the findings of Onwuka (2018) who reported that the high level of organic matter in the forest land of Umudike led to low bulk density, high total porosity and favoured transmission of water under saturated conditions.

The low saturated hydraulic conductivity observed under cultivated land may be attributed to the high bulk density and the mechanical disruption of the pore arrangements by tillage (Celik, 2005). The low bulk densities, high total porosities and saturated hydraulic conductivities and infiltration rates of coffee plantations and Natural forest maybe attributed to their high organic matter contents (Oguike *et al.,* 2006; Oguike and Mbagwu, 2009). Root systems and litter falls of trees from coffee plantation and Natural forest might have improved soil aggregation and porosity thereby increasing their saturated hydraulic conductivity (Banuhardt and Lascano, 1996). As organic matter decreased from Natural forest to continuously cultivated LUT, the total porosity reduced. This was consistent with the observations of Oguike *et al*. (2006).

Table 2: Bulk density, total porosity and hydraulic conductivity of soils under the different LUTs and soil depths

Land use	Bulk density($Mg\ m^{-3}$)	Total porosity (%)	Ksat ($cm\ hr^{-1}$)
0 – 20 cm			
Rubber plantation	1.61	39.70	15.00
Coffee plantation	1.50	44.00	18.00
Natural Forest	1.32	51.00	24.00
Cultivated land	1.55	42.00	13.20
Mean	1.50	44.18	17.55
%CV	21.50	15.80	17.70
20 – 40 cm			
Rubber plantation	1.78	33.00	13.20
Coffee plantation	1.64	39.00	15.00
Natural Forest	1.49	44.20	16.80
Cultivated land	1.58	40.80	11.40
Mean	1.62	39.25	14.10
%CV	16.80	28.15	10.60
40 – 60 cm			
Rubber plantation	1.92	28.10	11.40
Coffee plantation	1.75	34.50	12.00
Natural Forest	1.58	40.80	13.20
Cultivated land	1.60	40.10	10.20
Mean	1.71	35.88	11.70
%CV	12.70	16.10	16.10

3.2 pH and available phosphorus of the soil

The pH and available phosphorus of the soils varied significantly with the land use systems (Table 3). The pH of the soils ranged from 4.80 (strongly acidic) to 6.30 (moderately acidic) across the different land use systems and depths. At the depths of 0 – 20, 20 – 40 and 40 – 60 cm, forest land was observed to have the highest soil pH with values of 6.30, 6.00 and 5.70, respectively. The rubber plantation was observed to have the lowest pH at 0 – 20, 20 – 40 and 40 – 60 cm depth with values of 5.40, 5.00 and 4.80, respectively. Forest land had the highest available P at the three depths (Table 4) with values of 5.40, 2.62 and 1.63 mg kg^{-1} at 0-20, 20-40 and 40-60 cm depths respectively, while cultivated land had the lowest (P>0.05) available phosphorus at the three depths with values ranging from 1.50 to 1.6 mg kg^{-1}.

Forest LUT had a moderate acidic reaction whereas rubber plantation, coffee plantation and cultivated land had a strongly acidic soil reaction (Brady and Weil, 2002). As shown in Table 4. Soil pH decreased with depth.

Acidic condition of the soils could be attributed to the high annual rainfall in the study area and the consequent leaching of basic cation down the soil profiles (Eshett *et al*., 1990; Ahukaemere *et al*., 2014). Ahukaemere *et al*. (2014) also attributed the increased acidification of soils to greater oxidation of anions like sulphides and nitrites.

The decrease in pH with increase in soil depth may be as a result of larger organic matter content observed at the top soils which helped to bind tightly with aluminium ions and reduce their activity in the soil solution, thereby raising soil pH and reducing acidity (Nega and Heluf, 2013). The decrease of soil pH with depth might also be attributed to the increase in clay contents with depth which have the tendency to furnish hydrogen ions from clay colloidal surface to the solution thereby reducing soil pH. The moderately acidic nature of the soil under forest land could be attributed to the high exchangeable bases as a result of the presence of wastes, litter fall and roots (Alemayehu and Sheleme, 2013).

The available P content of the soil was lowest under continuously cultivated land relative to other LUTs. However, the differences between the soils were not significant (P>0.05). The lowest Available P content in the cultivated land might be related to phosphorus fixation (Yimer *et al.,* 2006). Available phosphorus was higher in the top than in the lower soil layers. According to (Landon, 1991) rating, Available P across all LUTs were low. The Available P deficiency in soils of the study area may be due to the inherent low-P status of the parent material and erosion losses.

Table 3 also shows the total nitrogen and organic matter content of soils under the different land use types and depths. The Table showed that at the depths of 0 – 20, 20 – 40 and 40 – 60 cm, forest land recorded the highest total nitrogen (0.18, 0.16 and 0.09g kg^{-1}, respectively) while cultivated land recorded the lowest total nitrogen (0.08, 0.06 and 0.05g kg^{-1}, respectively). Highest organic matter content was observed in forest land at all depths. Cultivated land had the lowest organic matter content at the three depths. However, there was no significant difference (P>0.05) between the soils of the different LUTs in total N content.

The relatively higher (P>0.05) total nitrogen content of the forest land could be associated with its relatively higher organic matter content which in turn resulted from plant and root biomass as well as residues being returned to the soil system. According to Landon (1991) ratings, the total nitrogen content in soil of the study area was found to be generally low. The principal cause for lower contents of total nitrogen comes from biomass removal during crop harvest and insufficient replenishment through manure or fertilizers

Organic matter content of the soils was in the range of 11.20 to 20.00 g kg^{-1}, this is rated low to high according to Enwezor *et al*. (1989). Organic matter was also found to decrease with depth; this could be attributed to the fact that organic residues are incorporated or deposited on the soil surface; thus making organic matter to be generally reduced at lower depth Ahukaemere *et al*., (2013). The lower organic matter content observed in cultivated land may be attributed to the effects of continuous cultivation that aggravates organic matter oxidation (Alemayehu and Sheleme, 2013; Wakene, 2011; Malo *et al*., 2003). The higher (P>0.05) organic matter under coffee plantation and forest land may be attributed to the continuous input and decomposition of litter falls and roots (Kleber *et al*., 2011; Wu *et al*., 2011). This was in agreement with the findings of Urisotle *et al*. (2006) who found out that the roots of grasses and trees and the fungi hyphae under coffee plantation and forest land, probably were responsible for the high organic matter content of soils on which they grow.

Table 3: selected chemical properties of soils studied under the different land use types

Land use	pH	Av. P (mg kg^{-1})	Total nitrogen (g kg^{-1})	Organic matter (g kg^{-1})
0 – 20cm				
Rubber plantation	5.40	4.51	0.14	15.30
Coffee plantation	5.90	4.76	0.17	16.00
Natural Forest	6.30	5.40	0.18	20.00
Cultivated land	5.70	1.61	0.08	13.50
Mean	5.83	4.07	0.14	15.70
%CV	3.80	22.80	54.10	34.10
20 – 40cm				
Rubber plantation	5.00	2.50	0.09	13.90
Coffee plantation	5.60	2.71	0.14	14.80
Natural Forest	6.00	2.62	0.16	14.90
Cultivated land	5.50	1.52	0.06	12.10
Mean	5.53	2.34	0.11	13.93
%CV	5.00	14.10	54.80	23.80
40 – 60cm				
Rubber plantation	4.80	1.60	0.06	12.10
Coffee plantation	5.10	1.53	0.08	12.00
Natural Forest	5.70	1.63	0.09	13.30
Cultivated land	5.00	1.50	0.05	11.20
Mean	5.15	1.57	0.07	12.15
%CV	2.60	10.90	53.90	16.10

4.0. Conclusion

This study shows that in Umudike, soils presently under rubber and coffee plantations are degraded relative to the soil of the natural forest soil. However, they are of higher quality than the soil used for arable crop production. Based on this findings, it is recommended that the cultural and soil fertility management practices adopted by farmers in the area should be reviewed and improved upon for better soil conservation.

References

Ahukaemere, C.M, Onweremadu, E.U, Ndukwu, B.N and Nkwopara U.N. (2014). Properties of soils of contrasting lithosequences in Southeastern Nigeria. *FUTO. J. Series.* Vol. 2(1).48-56.

Alemayeha, K. and Sheleme, B. (2013). Effects of different land use systems on selected soil properties in South Ethiopia. *Journal of Soil Science and Environmental Management*, 4(5): 100 – 107.

Asawalam, D. O., Chikezie, A. I., Eswaram, D. O. and Ano, A. O. (2009). Characterization of two benchmark soils of contrasting parent materials in Abia State, Southeastern. Nigeria. *Global journal of pure and applied sciences.* 16 (1): 23 – 29.

Benitez, E., R. Nogales, M. Campos, and Ruano F. (2006). Biochemical variability of olive- orchard soils under different management systems. *Applied Soil Ecology* 32: 221–231.

Banuhardt, R. L. and Lascano, K. J. (1996). Rain infiltration as affected by wheat residue amount and distribution in ridge tillage. *Soil Science Society of American Journal, 60:1908 – 1913*

Beer, J., Muschler, R., Kass, D., and Somarriba, E. (1998). Shade management in coffee and cocoa plantations. *Agroforestry Systems* 12: 229-249.

Brady, N.C., and R.R. Weil. 2002. *The Nature and Properties of Soils*. 12th ed. Prentice-haIl, INC., New Jersey

Celik, I. (2005). Land use effect on organic matter and physical properties of soil in a Southern Mediterranean highland of Turkey. *Soil and Tillage Research, 83 (2):270 – 277.*

Chukwu, G. O., Tarfa, B. D. and Amapu, I. Y. (2014). Linking pedology and extension:
Emerging trend in optimizing fertilizer recommendations and sustaining soil health in Nigeria. *Sky journal of Soil Science and Environmental management*, 3(5): 42 – 49.

Delarue, J. (2009). Developing Smallholder Rubber Production. Lessons from AFD's Experience. Evaluation and Capitalisation Series, No. 26.

Duah-Yentumi, S., Ronn, R. and Christensen, S. (1998). Nutrients limiting microbial growth in a tropical forest soil of Ghana under different management. *Applied Soil Ecology*, 8: 19-24.

Duguma, B., Gochowski, J., and Bakala, J. (2001). Smallholder cacao (Theobroma cacao Linn.) cultivation in agroforestry systems of West and Central Africa: Challenges and opportunities. *Agroforestry Systems*, 51:177 –188.

Ekanade, O., Adesina, F.A. and Egbe. N.E. (1991). Sustaining tree crop production under intensive land use: An investigation into soil quality differentiation under varying cropping patterns in western Nigeria. *J. Ev. Manage.* 32: 105-113.

Eshett, E.T., J.A. Omueti and A.S. Juo. (1990). Physico-chemical, morphological and clay Mineralogical properties of soils overlying basement complex rocks in Ogoja, Northern Cross River State of Nigeria. *Soil Sci. Plant Nutr.* 36(2): 203- 214.

FAO (2010). Global Resources Assessment 2010. Country Report, Ghana, FRA 2010/077, Rome.

Gebeyaw, T. (2007). Soil Fertility Status as Influenced by Different Land Uses in Maybar Areas of South Wello zone, North Ethiopia". M.Sc. Thesis, Haramaya University, Ethiopia. 2007.

Gee, G. W. and Or, D. 2002. Particle-size analysis. In:Dane, J. H., Topp. G. C. (Eds.). Methods of soil Analysis Madison. *Soil Science Society of America, Madison, Wisconsin, USA*, Pp. 255-293.

Kauffman, J. B., Cummings, D. L. and Ward, D. E. (1998). Fire in the Brazilian Amazon. 2. Biomass, nutrient pools and losses in cattle pastures. *Oecologia* 113:415-427.

Kleber, M., Nico, P. S., Plante, A. F., Filley, T., Kramer, M., Swanston, C. and Collins, P. (2011). Old and stable soil organic matter is not necessarily chemically recalcitrant. Implications for modelling concepts and temperature sensitivity. *Global Change and Biology, 17: 1097 – 1107.*

Kotto-Same, J., Woomer, P. L., Appolinaire, M., and Louis, Z. (1997). Carbon dynamics in slash-and-burn agriculture and land use alternatives of the humid forest zone in
Cameroon. *Agriculture, Ecosystems and Environment* 65:245-256.

Landon, J. R. (1991). *Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Longman Scientific and Technical, New York, NY, USA, 1991.

Li, G., Ma, D., Zhang, Y., Zheng, W. and Wang, P. (2013). Coffee consumption and risk of colorectal cancer: a meta-analysis of observational studies. *Public Health Nutr*. 16, 346–357.

Li, J., Lin, W. and Zhou, L. (2016). Effects of long-term intercropping coffee on rubber soil nutrients and soil enzymes. *Southwest China J. Agric. Sci.* 29, 1371–1374.

Malo, D. D. Schumacher, T. E. and Doolittle, J. J. (2003). Long-term cultivation impacts on selected soil properties in the Northern Great Plains. *Soil Tillage Res., 81: 277 – 291.*

Nega E. and Heluf G. (2013). Effect of land use changes and soil depth on soil organic matter,TN and available phosphorus, contents of soils in senbat watershed, western Ethiopia. *ARPN Journal of Agricultural and Biological Science,* 8(3): 206 – 212.

Nelson, D.W., and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p.961-1010 In J.M. Bartels et al. (ed.) Methods of soil analysis. Part 3 Chemical methods. SSSA Book Ser No.5. SSSA, Madison, WI.

Nigerian Meteorological Agency. (2015). Seasonal rainfall prediction for 2015. *Nigeria Meteorological Publications. Maitama, FCT Abuja.*

Okolo, C. C., Nwite, J. N., Ezeaku, P. E., Eke, N. C., Ezeudo, V. C. and Akamigbo, F. O. R (2013). Assessment of Selected Physiochemical Properties of Soils for Site Suitable For Waste Disposal in Abakaliki, South East, Nigeria.*Journal of Resources Development and Management, 1: 26 – 29.*

Oguike, P. C., Chukwu, G. O and Njoku, N. C. (2006). Physio-chemical properties of a haplicacrisol in South Eastern Nigeria amended with rice waste and NPK fertilizer. *African Journal of Biotechnology, 5: 1058 – 1061.*

Oguike P. C. and Mbagwu J. S. C. (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World Journal of Agricultural Science, 5(1): 63 – 69.*

Oguike, P. C. and Onwuka, B. M. (2017). Variations in

Texture, Water Retention and Transmission, Organic Matter and pH of Soils under Selected Land Use Systems at UbakalaUmuahia, South-Eastern Nigeria. *Journal of Scientific and Engineering Research,* 2017, 4 (7):147-155.

Ogunkunle A. O. and Eghaghara, O. O. (1992). Influence of land use on soil properties in a Forest region in Southern Nigeria. *Soil Use and Manage*. 8: 121-125.

Ricketts, T. H., Daily, G. C., Ehrlich, P. R. & Michener, C. D. (2004). Economic value of tropical forest to coffee production. Proc. Natl. Acad. Sci. USA 101, 12579 –12582.

Shepherd, G., Bareh, R. J. and Gregory, P. J. (2000). Land use affects the distribution of soil inorganic nitrogen in small holder production systems in Kenya. *Biology and fertility of Soils*, 31: 348 – 355.

Thomas, G.W. (1982). Exchangeable cation; In Page A.L et al (eds) Methods of Soil Analysis Part 2. Agron. Monography, a second edition, ASA and SSSA Madison. Pp 159-165.

Van Beilen J. B, and Poirier Y. (2007). Establishment of new crops for the production of natural rubber. Trends Biotechnol. 2007 Nov; 25(11):522-9. Epub 2007 Oct 22. Review. Pub Med PMID: 17936926.

Venkatachalam, P., Geetha, N., Sangeetha, P., and Thulaseedharaan, A. (2013). Natural rubber producing plants: An Overview. *African Journal of Biotechnology* Vol. 12(12), 1297-1310.

Wakene, N. (2011). Assessment of important physiochemical properties of Dystricudalf (DystricNitosols) under different management systems in Bakoarea.Western Ethiopia. M.Sc. thesis submitted to School of Graduate Studies, Alemaya University, Ethiopia. P. 93.

Wall, A., and Hytönen, J. (2005). Soil fertility of afforested arable land compared to continuously forested sites. *Plant and Soil*, 275: 245-258.

WRM Briefing (2008). Oil palm and rubber plantations in Western and Central Africa: An Overview.
[http://www.wrm.org.uy/publications/briefings/Western_Central_Africa.pdf.],(accessed on 2019, May 4).

Wu, W., Yang, P., Tang, H., Dagaro, L. and Shibasaki, R. (2011). Regional variability of the effects of land use systems on soil properties. *Agricultural Sciences in China, 6(11): 1369 – 1375.*

Yimer, F., Ledin, S. and Abdelkadir, A. (2006) "Concentrations of exchangeable bases and cation exchange capacity in soils of cropland, grazing and forest in the Bale Mountains, Ethiopia, *Forest Ecology and Management*, 256 (6): 1298–1302.