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VARIATION IN SOIL PHYSICAL AND CHEMICAL PROPERTIES UNDER DIFFERENT LAND USES IN OKO-IRO FOREST RESERVES, OYO STATE SOUTH WESTERN NIGERIA.

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ABSTRACT

The understanding of soil physical and chemical properties is important for environmental management and sustainability in any forest ecosystem. Soil physical and chemical properties under different land uses was undertaken to assess the nutrient and fertility status for sustainable environmental management. Ten soils samples each collected within the three location (natural forest, plantation and farmland) sites were analyzed for soil texture, bulk density, porosity, water holding capacity, pH, electrical conductivity, organic matter content, total nitrogen, available phosphorus, Na, K, Ca, Mg, Zn, Cu, Fe and Mn using standard instrumentation techniques. Texturally, the soils were predominantly loam to sandy loam with mean percentage of sands ranging from 52.00±1.24 to 80.51±1.45 %. Soil pH of the natural forest (6.67±0.07) is slightly acidic while those of plantation forest (5.27±0.02) and farm land are acidic in nature (4.49±0.01). Lower mean values of porosity (47.02±1.15 %), higher mean values of bulk density (1.45± 0.05gcm^3), water holding capacity (65.25± 2.61%), organic matter content (6.27±0.38%), total nitrogen (1.41±0.11%) and available phosphorus (0.99± 0.04%) were found in natural forest soil than tree plantation and farmland. Higher mean values were also observed for Na, K, Ca, Mg, Zn, Cu, Fe and Mn in the natural forest soils. There were significant differences in soil physical and chemical properties among the three land use at P<0.05. The results of study showed that soil physical and chemical properties were distinctiveness interrelated and soil nutrients under natural forest were higher and more fertile due to the litter accumulation

Keywords: Soil properties, Soil quality, Forest ecosystem, Nutrient cycle, Environment

Introduction

Soil as a major part of ecosystem is an important natural resource that ensures continuous growth and management of natural vegetation by providing supports, nutrients, water, fibre, fuel, mineral resources, food as well as other ecosystem services such as regulation of climate and production of oxygen (Dominati *et al.*, 2010; FAO,2005; Robinson *et al.*, 2017). The qualities of soil physical, chemical and biological properties determine the appropriateness of the soil for its numerous usages (Mobley, 2009; Khan *et al*, 2013). However, its quality and spatial variability can be linked to several factors such as climate, geology, topography, vegetation as well as human activities such as construction, farming, erosion, deforestation, over exploitation and many more (Umali *et al.*, 2012; Akintola *et al.*, 2020 a,b). A slight change in the aforementioned factors may modify soil ecosystem, which in turn can affect the overall soil quality (Errington *et al*., 2018). Soils and vegetation are mutually associated with each other. Soils support plant growth by acting as store house of water and serve as substrate to hold plant firmly through their root, vegetation as well stabilize the soil, maintaining water and nutrient cycling thus preventing it from degradation and desertification, (FAO, 2005). However, the increase in the economic and developmental growth has led to increase in the demand of vegetation such as grasses, forest trees, shrubs, forest foods and products which in turn has put the soil under vigorous stress, risk of degradation and numerous exposure to anthropogenic activities (FAO, 2005; Errington *et al.*, 2018).

These activities according to Errington (2008) may be biological (the removal of plant material); physical (loss of soil structure) and chemical, (introduction of contaminants). Due to different properties of soil (the physical, chemical and biological, the assessment of the quality of soil is somewhat difficult, as their amalgamation is needed to the soil potency (Chandra *et al.,* 2016). Thus frequent studying and understanding these properties will help to know the strength of the soil at a particular place and at a particular time (Tsui *et al.,* 2004). The main part of the global ecosystem is sheltered by forest land, the microorganism in the soils such as earthworms, ant, centipede, nematodes and so on control the rate of decomposition, soil organic matter and generally, the biogeochemical processes that administrate the physic chemical properties of soil of a given forest type and the productivity of forest ecosystems (Noguez *et al.,* 2008). Forest types with various tree species, differ in quality of litters and root exudates which may in due course bring discrepancy in soil properties and may eventually affects the soil microbes (Yimer *et al.,* 2006; Chandra *et al.,* 2016).

Nowadays, natural forests all over the world are formed through natural regeneration due to disturbances by anthropogenic activities or by extreme natural events (Wang and Yang 2007; Yang *et al*., 2010). Approximately 30 % of world's total land area is covered by forest; these forests are the source of global terrestrial carbon in which forest ecosystem plays a major role in carbon sequestration from increasing atmospheric carbon dioxide, as it covers the major portion of terrestrial land (Myneni *et al.,* 2001; Holden and Treseder 2013). Burton *et al.* (2007) predicted that plantations generally are inferior to naturally regenerated forest stands in nutrient cycling and soil quality but some studies suggest that variations in soil properties probably depend on the specific forest ecosystems and climatic factors. Thus, to establish sustainable land management for forest conservation and reforestation, it is necessary to assess the variation in soil physical and chemical properties and soil nutrient status between land use types

Materials and Methods

Study area Description

Oko-Iroo Forest Reserve which lies between Latitude 8° 00' and 8° 20' N; and Longitude 8° 00' and 8° 00' N is located between Oko and Iroo villages within Ogo Oluwa Local Government Area in Ogbomoso, Oyo State. The reserve is accessible through Iresa/Iko and Ejigbo to Iko road. The reserve is surrounded by villages such as Iresa, Tafon, Ijado, Ilogbo, Iganna, Alagbayu, and so on in Ogbomoso (Figure 1 and 2), Oyo state and also close to Ejigbo in Osun State. The forest reserve belongs to Oyo State Government

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(Aderounmu *et al*., 2020). The Oko-Iroo forest reserve is about 50km^2(5,000ha) and roughly triangular in shape, 75.07km^2 (7,507Ha). However, with the level of depletion and deforestation through illegal felling and encroachment of individual forest reserve in the state as reported by Sanwo *et al.* (2015) and Ige, (2017), the actual area of land covered in forest reserve is now about 5,000ha.

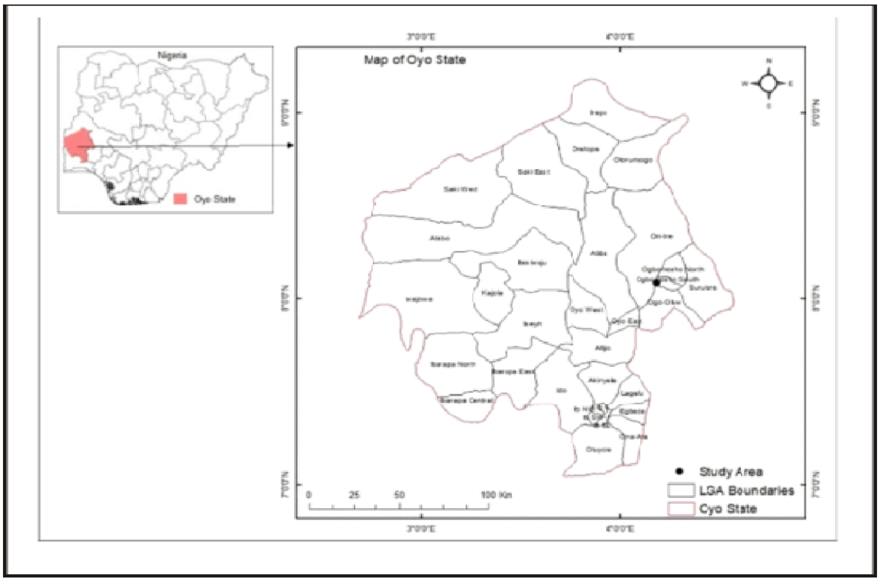

Figure 1. Map of Oyo state showing the study area (Aderounmu *et al*., 2020)

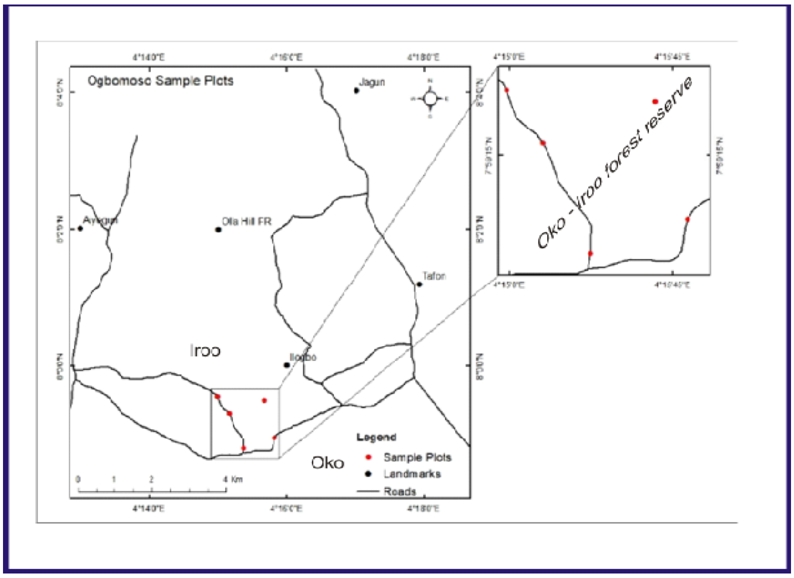

Figure 2. Location map of the study area (Aderounmu *et al*., 2020)

The reserve fall within the Southern Guinea Savanna which occurs in part of Oyo, Osun, Ondo and Kwara states in Nigeria. The natural vegetation in the study area is sub-humid type and is characteristically dominated by tall grasses which often attain the height of 2-3m during the wet season (Aderounmu *et al.*, 2020). The grasses grow in dense tufts and are prone to burning during the dry season when the grass dries. In areas, such as the study area where the vegetation has not been intensively disturbed by man, the vegetation consists of savanna woodland in which trees predominantly range between 12-15m in height. Tree species found in the natural forest are *Triplochyton scleroxylon, Terminalia superb, Spondias mombin Albizia lebbeck, Tetrapleura tetraptera and Treculia Africana* while *Tectona grandis, Delonix regia, Acacia nilotica, Adansonia digitata, Senna siamea, Azadirachta indica* and *Cedrela odorata* in plantation forest . The plants found in the farmland are maize, cassava, yam among others.

The climate is characterized by alternation of wet season lasting from April to October and dry season from November to March with annual rainfall ranges from 1,300 – 1,500mm and average humidity of about 65%, the average temperature is about 26^0c. The topography of the study area is undulating with elevation values ranging from 328m-412m and average values of 364m above sea level (Aderounmu *et al.*, 2020). The drainage pattern of the study area is dendritic and it is drained by river Aduniyi, Ogegun and Ora (Figure 3).

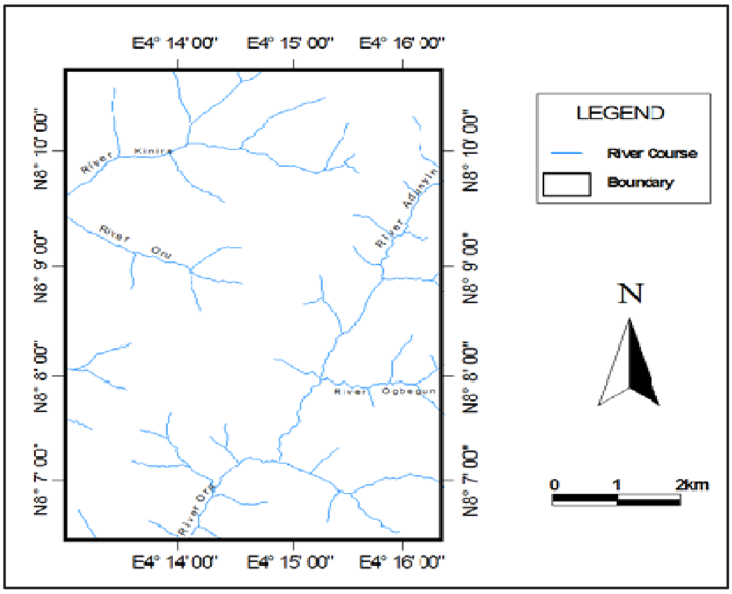

Figure 3. Drainage Network of the study area (Oladunjoye *et al.*, 2013)

Figure 4. Geological map of Ogbomosho Area (Oladunjoye *et al.*, 2013)

Geologically, the study area is located within the southwestern Nigeria basement complex. The rocks unit is made up of ancient gneiss-migmatite series and meta-sedimentary series (Afolabi *et al.*, 2013). They contain biotite, hornblende, quartz, plagioclase, microcline and rarely pyroxene. The meta-sedimentary series include quartzite and quartz-schists. The quartzite occurs as long elongated ridges trending NW-SE and mostly massive schistose quartzites with micaceous minerals alternating with quartzo-feldspathic rocks which are common in the southwestern part of Ogbomoso (Figure 4).

Collection and Preparation of Soil Samples

Ten composite soil samples were randomly collected from each of the location sites i.e. natural forest, plantation and farming land area at the depth of 0-20cm using an auger. The samples were immediately put into the polythene bags and labeled accordingly. The undisturbed soil samples were also collected using core cutters and sealed immediately on both edges with melted candle wax on the field to prevent moisture loss. The collected composite soil samples were air dried, gently crushed and sieved through 2 mm mesh for laboratory analysis.

Laboratory Analysis

The physical (particle size distribution, soil moisture content, water holding capacity, bulk density, particle density and soil porosity tests) and chemical analyses (pH, electrical conductivity, organic matter content, total nitrogen, available phosphorus, Na, K, Ca, Mg. Zn, Cu, Fe and Mn) were carried out on the collected soil samples. Particle size distribution test was carried out using hydrometer (method of Brown (2003). Bulk density (BD) were analyzed by method described by Blake and Hartge (1986) while water holding capacity (WHC) and porosity were analyzed by the method described by Black *et al.* (1965). Soil pH and electrical conductivity (EC) were obtained using soil: distilled water (1:2.5), while the organic carbon contents of the soils were determined using Walkley and Black (1934) method and then multiplied by 1.724 to calculate soil organic matter content. Total nitrogen (TN) was determined

using the method given by Stanford and smith (1978) and Kjeldahl nitrogen (Kjeltech analyzer) (Jackson 1958) while available phosphorous were estimated by method of Olsen *et al.* (1983) and stannous chloride method given by Sparling *et al.* (1985) followed by hot plate digestion in HNO_3:$HClO_3$ (3:1) at 180ºC for 6 h. The exchangeable cation was extracted using 1M ammonium acetate solution; Ca and Mg were analyzed from the extract by EDTA titration method while K and Na were done by flame photometer. Analysis of Zn, Cu, Fe and Mn were analyzed using atomic absorption spectrophotometer (AAS, MEDTECH).

Data Analysis

Data were presented as mean ± SD (standard deviation). One-way Analysis of Variance (ANOVA) was used for determination of variability among the study locations while the Duncan Multiple Range Tests was used for the separation of means (SPSS 20.0). Pearson correlation was used to determine the relationship among the determined parameters.

Results and Discussion

Physical Characteristics of Soil

The physical characteristic of the soils from the three studied locations is presented in Table 1. The soils under the three different land uses were predominantly loam to sandy loam with mean percentage of sands ranging from 52.00±1.24 to 80.51±1.45 %. The soil particle sizes under the three sites were significantly different ($p < 0.05$). The observed differences in the soil particle sizes may be due to the mineralogical composition of the parent materials from which the soil is formed and different vegetation types (Githae *et al*, 2011; Akintola *et al.*, 2020a and 2020b). This may in turn lead to variation in soil pH and exchangeable cations (Finzi *et al.*, 1998).

Table 1: Physical characteristics of the soil samples

Parameters	**Land use Types**		
	Natural Forest	Plantation Forest	Farmland
Sand (%)	$52.00±1.24^{c}$	$80.51±1.45^{a}$	$73.12±1.01^{b}$
Silt (%)	$35.22±0.51^{a}$	$10.95±0.25^{b}$	$7.38±0.35^{c}$
Clay (%)	$12.78±0.21^{b}$	$8.86±0.12^{c}$	$16.11±0.17^{a}$
Bulk Density (BD) (%)	$1.45± 0.05^{a}$	$1.31±0.02^{b}$	$1.21±0.01^{c}$
Porosity (%)	$47.02±1.15^{c}$	$53.34±2.11^{b}$	$69.68±2.78^{a}$
Water holding capacity (WHC) (%)	$65.25± 2.61^{a}$	$51.09± 1.89^{b}$	$45.11±1.09^{c}$

Values are Mean± standard deviation and letters represents different significant at P<0.05

The bulk density of the soils (Table 1) showed that soils from the natural forest (1.45± 0.05%) had a significantly higher mean values than those from plantation (1.31±0.02%) and farmland (1.21±0.01%) and this is similar to what is obtainable in Akintola *et al*. (2020b). The mean values of porosity from natural, plantation and farmland soils were 47.02±1.15^{c} %, 53.34±2.11^{b} % and 69.68±2.78^{a} % respectively. The mean values of WHC showed higher values in natural forest (65.25± 2.61%) followed by plantation forest (51.09± 1.89%) and farmland soils (45.11±1.09%). The significantly high values of water holding capacity, bulk density and lower porosity from natural forest soils may be due to the forest canopies which give maximum protection to the soil from heat and erosion due to rainfall which in turn helps in retaining the nutrients in the soil (Akintola *et al.*, 2020a). The presence of litters such as fallen leaves and stems on the top layer of soil and higher organic carbon content may result into high WHC (Paudel and Sah, 2003).

Chemical Characteristics of the Soils

The pH of the soils from the natural forest (6.67±0.07) is slightly acidic while those of plantation forest (5.27±0.02) and farm land are acidic in nature (4.49±0.01) as shown in Table 2. The acidic nature of the soil may be due to decomposition of organic materials such as plant remains and litters and accumulation of organic matter on the floor (Ushio *et al.*, 2010).The differences in soil pH under the three varieties perhaps echo the composition of the parent material as well as differences in vegetation types (Githael *et al.*, 2011). The mechanisms by which tree species influence soil acidity and exchangeable cations comprise inter-specific differences in the uptake of exchangeable bases, nitrogen fixation, production of litter high in organic acid content and the stimulation of mineral weathering as stated by Finzi *et al.* (1998). Thus, soil pH greatly influenced the availability of nutrients for plants as well as indication of soil fertility (Zhao *et al.* 2012, Liu *et al*, 2020). The electrical conductivity values were significantly higher in natural forest (213.22±6.71 µS/cm) soils than plantation forest (101.22±2.68 µS/cm) and farmland (67.99±1.65 µS/cm) soils. The high in the natural and plantation forest soil EC values can be due the increase in nutrients from the decomposition of litters of leaves, stems and dead micro organism in the soils. This may also be as a result of factors governing the solubilization, sorption and mineralization/immobilization processes which may exert a great influence on the amounts of ions governing soil EC (Carmo *et al.,* 2016). Electrical conductivity as an important soil property affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms that influence the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide (USDA, 1998). Since the values of the EC for soils under the three activities is less than 1000 µS/cm (1dS/m), the soils can be considered as non-saline soils and cannot brunt important microbial processes, such as nitrogen cycling, production of nitrous and other N oxide gases, respiration, and decomposition but reduces the populations of plant-parasitic nematodes and nitrogen losses (USDA, 1998). Organic matter content was significantly higher in the natural forest soils with mean values of 6.27±0.38%, followed by plantation forest (4.56±0.15%) and farmland (2.18±0.21%) soils. The natural forest (1.41±0.11%) and tree plantation (0.83±0.02%) had higher mean values of total nitrogen in the soils than farmland soil (0.51±0.01%). The available phosphorus was significantly highest in natural forest soil (0.99± 0.04%) than tree plantation (0.71±0.01%) and farmland soils (0.38±0.01%). The values of OMC, TN and AP were higher than those obtainable from similar study carried out at olokemeji forest reserve by Akintola *et al.* (2020 b). This could be attributed to the location, topography, anthropogenic activities, and mineralogical composition of the rocks in the area as well as vegetation types. Calcium had the highest mean concentrations among the exchangeable cations in the studied soils. The mean values of Ca were higher in the natural forest (7.01±1.11mg/kg,) than tree plantation (4.25±0.52 mg/kg) and farmland (2.11±0.05 mg/kg) soils. The mean values of Mg in the soils from natural forest were 1.28±0.06 mg/kg, 0.82±0.02 mg/kg from tree plantation and 0.39±0.02 mg/kg from farmland. While the mean values of Na and K in soils from natural forest were 1.89±0.07 and 0.81± 0.02 mg/kg, 1.01±0.02 and 0.48± 0.01 mg/kg from tree plantation and 0.68±0.01 and 0.22±0.01 mg/kg from farmland (Table 2). Generally, the mean values of exchangeable cations were significantly higher in the natural forest soils than tree plantation and farmland soils. These values were higher when compared with similar works carried out at Onigambari and Olokemeji forest reserves (Akintola *et al.*, 2020 a and b). Iron (Fe) showed significantly higher mean values in the soil from natural forest (201.54±10.11mg/kg) than tree plantation (162.23±5.89 mg/kg) and farmland (76.88±2.67 mg/kg) soils. The mean values of Zn in the soils from natural forest were 56.21±3.56 mg/kg, tree plantation (35.45±2.56 mg/kg) and farmland (21.45±1.11 mg/kg) while the mean values of Cu and Mn in soils from natural forest were 45.89±1.45 mg/kg and 148.90±3.56 mg/kg, tree plantation (24.24±0.89 and 112.71±2.87 mg/kg) and farmland (52.67±1.47 and 52.67±1.47 mg/kg) respectively (Table 2). The lowering in the soil organic matter in farm land soils directly depleted the concentration of essential nutrients. Additionally, variation in accessibility of nutrients is explained by the pattern of forest succession that is responsible for the difference in organic matter content (Akintola *et al*,, 2020a). Generally, high amount of soil nutrients noted in the soils under natural forest may be attributed to less or no anthropogenic inputs such as human activities as well as soil stability due to coverage from the forest which prevents them from rain and heat effects. Since nutrients from leaves return to the soil through litters, degeneration and decomposition forming organic matter in a forest ecosystem which in turn leads to nutrient richness and availability (Akintola *et al.*, 2020a). Thus, soil organic matter governs the physico-chemical characteristics of soils and provides favorable conditions for the survival of plant growth (Horwath 2005).

Table 2: Chemical Characteristics of Soils

Parameters	Land use Types		
	Natural Forest	Plantation Forest	Farmland
pH	6.78±0.07[b]	5.27±0.02[a]	4.49±0.01[a]
Electrical Conductivity(EC)µS/cm	213.22±6.71[a]	101.22±2.68[b]	67.99±1.65[c]
Organic matter content(OMC)%	6.27±0.38[a]	4.56±0.15[b]	2.18±0.21[c]
Total Nitrogen(TN)%	1.41±0.11[a]	0.83±0.02[b]	0.51±0.01[c]
Available phosphorus(AP)%	0.99± 0.04[a]	0.71±0.01[b]	0.38±0.01[c]
Na (mg/kg)	1.89±0.07[a]	1.01±0.02[b]	0.68±0.01[c]
K (mg/kg)	0.81± 0.02[a]	0.48± 0.01[b]	0.22±0.01[c]
Ca (mg/kg)	7.01±1.11[a]	4.25±0.52[b]	2.11±0.05[c]
Mg (mg/kg)	1.28±0.06[a]	0.82±0.02[b]	0.39±0.02[c]
Fe (mg/kg)	201.54±10.11[a]	162.23±5.89[b]	76.88±2.67[c]
Zn (mg/kg)	56.21±3.56[a]	35.45±2.56[b]	21.45±1.11[c]
Cu (mg/kg)	45.89±1.45[a]	24.24±0.89[b]	13.67±0.46[c]
Mn (mg/kg)	148.90±3.56[a]	112.71±2.87[b]	52.67±1.47[c]

Values are Mean± standard deviation and letters represents different significant at $P<0.05$

Table 3

Parameters	WHC	EC	BD	Porosity	PH	OMC	TN	TP	Na	K	Ca	Mg	Fe	Zn	Cu	Mn
WHC	1	.590**	.838**	-.800**	.785**	.715**	.834**	.859**	.850**	.845**	.830**	.773**	.884**	.866**	.483**	.839**
EC		1	.647**	-.627**	.620**	.606**	.623**	.628**	.649**	.653**	.632**	.568**	.636**	.629**	.369*	.599**
BD			1	-.987**	.967**	.930**	.944**	.882**	.942**	.935**	.923**	.888**	.889**	.879**	.668**	.802**
Porosity				1	-.975**	-.950**	-.925**	-.853**	-.928**	-.921**	-.915**	-.869**	-.855**	-.844**	-.687**	-.738**
PH					1	.901**	.961**	.846**	.928**	.919**	.899**	.855**	.885**	.827**	.701**	.742**
OMC						1	.899**	.801**	.931**	.891**	.879**	.821**	.806**	.788**	.761**	.799**
TN							1	.907**	.919**	.922**	.949**	.911**	.952**	.959**	.699**	.898**
TP								1	.885**	.899**	.918**	.895**	.889**	.829**	.588**	.856**
Na									1	.917**	.908**	.901**	.920**	.911**	.719**	.866**
K										1	.931**	.901**	-.956**	.935**	.709**	.879**
Ca											1	.913**	-.901**	.921**	.709**	.912**
Mg												1	-.861**	.889**	.581**	.952**
Fe													1	.891**	.602**	.918**
Zn														1	.545**	.907**
Cu															1	.610**
Mn																1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations among Soil Physical and Chemical Properties

Physical and chemical properties of soils are important soil quality indicator that show the difference, interactions and close relationship with each other (51). Table 3 showed the relationship among the determined parameters in the soil samples. Significant correlation (P < 0.01) was observed among the determined chemical parameters of the studied soils (Table 3). Water holding capacity (WHC) was strong and significantly correlated with bulk density (0.838), porosity (-0.800), pH (0.785), organic matter content (0.715), total nitrogen (0.834), available phosphorus (0.859), Na (0.850), Ca (0.845), Mg (0.830), K (0.773), Fe (884), Zn (0.866) and Mn (0.839) but weak to moderate correlated with Cu (0.483) and EC (0.590). Likewise, EC, bulk density and pH showed strong and positive correlation with other determined parameters with the exception of porosity that indicated negative but strong relationship with others (Table 3).

Organic matter content was strong and significantly correlated with total nitrogen (0.899), available phosphorus (0.801), Na (0.931), Ca (0.891), Mg (0.879), K (0.821), Fe (0.806), Zn (0.788), Cu (0.761), and Mn (0.799). The strong relationships that exist between soil organic matter and other parameters is an indication of its influence on series of soil properties and nutrient cycle in the soil (Loveland and Webb, 2003; Liu *et al*., 2020). Six *et al*. (2002) stated that increase in soil organic matter positively influence the decomposition of animal and plant residues as well as humus by soil enzymes, thereby releasing nitrogen and potassium. Thus, soil organic matter governs the physico-chemical characteristics of soils and provides favorable conditions for the survival of plant growth (Horwath 2005). Soil pH strongly affects soil processes such as nitrogen cycling which impact the soil chemical, physical and biological processes (Akintola *et al.*, 2020a).

Conclusion

This study has shown that natural forest significantly affects soil physical and chemical properties, and most of these properties showed the highest and lowest values in the natural and farmland soils respectively. Since nutrients from leaves return to the soil through litters, degeneration and decomposition forming organic matter in a forest ecosystem thus, soil organic matter governs the physico-chemical characteristics of soils and provides favorable conditions for the survival of plant growth. Thus, soil physical and chemical properties should be plainly used in assessing the effect of management practices on soil quality and layout planning in vegetation restoration. Although, the study has shown that soil properties in the forest ecosystem are significantly influenced by multiple environmental factors such as land use types, however further studies should be done to elucidate the complex interactive relationships among soil physico-chemical and biological properties, vegetation, land use and its history and management as well as to develop soil physico-chemical and biological quality indicators as a means of restoring degraded ecosystems, vegetation and sustainable land management.

References

Aderounmu A. F., Akintola, O.O., Shittu A. J., Adeniran, T., Abodunrin E. K., Agboola F. and Olokeogun, O. (2020): Flora Biodiversity Assessment of Oko-Iroo Forest

Reserve in Oyo State. Technical report. Forestry Reasearch Institute of Nigeria. Pp22

Afolabi, O. A., Kolawole, L. L., Abimbola, A. F., Olatunji, A. S and Ajibade, O. M. (2013): Preliminary tudy of the Geology and Structural Trends of Lower Proterozoic Basement rocks in Ogbomoso, SW Nigeria. *Journal of Environment and Earth Science*, 3(8): 82-95

Akintola, O.O., Bodede, A.I and Abiola, I.O. (2020a): Physical and Chemical Properties of Soils in Gambari Forest Reserve. *Journal of Bioresource and Management.*, 7 (2): 57-67.

Akintola, O. O., Bodede, A. I., Smart, M., Adebayo, A. G., and Sulaiman, O. N. (2020): Assessment of Soil Properties Under Different Land Use Types in Olokemeji Forest Reserves in Ogun State Southwestern Nigeria, *Journal of Bioresource Management*, 7 (3):73-84

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L and Clark, F.E (1965): Methods of soil analysis. Monogr 9. *American Society of Agronomy*, ASA, Madison

Blake., G. R and Hartge, K.H (1986): Bulk density. In: Methods of Soil Analysis. Agronomy No. 9, 2nd ed., Madison, WI: pp. 363–375.

Brown, R.B. (2003): Soil Texture. Fact Sheet SL-29., University of Florida, Institute of Food and Agricultural Sciences.

Burton , J., Chen, C.R and Xu, Z.H. (2007): Gross nitrogen transformations in adjacent native and plantation forests of subtropical Australia. *Soil Biology and Biochemistry* 39:426–433. doi:10.1016/j.soilbio.2006.08.011

Carmo, D.L., Lima, L.B and Silva, C. A (2016). Soil Fertility and Electrical Conductivity Affected by Organic Waste Rates and Nutrient Inputs. *Revista Brasileira de Ciência do Solo*, *40*, e0150152.https://doi.org/10.1590/18069657rbcs20150152

Chandra, L. R., Gupta, S and Singh, N. (2018): Impact of forest vegetation on soil characteristics: a correlation between soil biological and physico-chemical properties. *Biotechnology* 6:188-200. DOI 10.1007/s13205-016-0510-y

Dominati, E., Patterson, M and Mackay, A. (2010): A framework for classifying and quantifying the natural capital and ecosystem services of soils. *Ecology*. 1858–1868. doi:10.1016/S1002-0160(08)60073-9

Errington, I., King, C.K., Houlahan, S., George, S.C., Michie, A. and Hos, G.C (2018): The influence of vegetation and soil properties on springtail communities in a diesel-contaminated soil. *Science of Total Environment*, 619–620 : 1098–1104

Githae1, E.W., Gachene, K.K and Njoka, J.T (2011): Soil physicochemical properties under *Acacia Senegal* varieties in the dryland areas of Kenya. *African Journal of Plant Science* 5(8): 475-482,

FAO (2005): Soils are the foundation for vegetation. **www.fao.org/soils-2015**; retrieved on 12th of December, 2020

Finzi, A.C, Charles, D.C and Breemen, N.V. (1998): Canopy tree-soil interactions within temperate forests: Species effects on pH and cations. *Ecology and Applied*, 8: 447-454

Holden, S.R, and Treseder, K.K (2013): A meta-analysis of soil microbial biomass responses to forest disturbances. *Front Microbiolology* 4:1–17

Horwath, W.R (2005): The importance of soil organic matter in the fertility of organic production systems, Western Nutrient Management Conference

Ige P. O (2017): Relationship between tree slenderness coefficient and tree and standgrowth characteristics for Triplochiton species in Gambari forest reserve. *Journal of Forestry Research and Management.* 14 (2): 166-188.

Jackson, M. L. (1958): Soil chemical analysis. Prentice Hall, Englewood Cliffs

Khan, F., Hayat, Z., Ahmad, W., Ramzan, M., Shah, Z., Sharif, M., Mian, I.A. and Hanif, M. E. (2013): Effect of slope position on physico-chemical properties of eroded soil. *Soil Environmental journal*. 32: 22–28.

Liu, R., Pan, Y., Bao. H., Liang, S., Jiang, Y., Tu, Y., Nong, J and Huang, W. (2020): Variations in Soil Physico-Chemical Properties along Slope Position Gradient in Secondary Vegetation of the Hilly Region, Guilin, Southwest China. *Sustainability*, 12:1303-1309 doi:10.3390/su12041303

Loveland, P. and Webb, J. (2003): Is there a critical level of organic matter in the agricultural soils of temperate regions: A review. *Soil Tillage Resource.* 70: 1–18.

Mobley, M.L (2009): Monitoring Earth's critical zone. *Science*, 326:1067–1068.

Myneni, R. B., Dong, J. and Tucker, C. J (2001): A large carbon sinks in the woody biomass of Northern forests. *Postulate, Natural and Academic Science* 98:14784–14789. doi:10.1073/pnas.261555198

Noguez, A. M., Escalante, A. E., Forney, L. J., Mendoza, M. N., Rosas, I., Souza, V. and Oliva, F. G (2008): Soil aggregates in a tropical deciduous forest: effects on C and N dynamics, and microbial communities as determined by t-RFLPs. *Biogeochemistry* 89:209–220. doi:10. 1007/s10533-008-9214-7

Oladunjoye, M., Adabanija, M. and Adeboye, O. (2013): Groundwater Prospecting and Exploration in a Low Potential Hard Rock Aquifer: Case Study from Ogbomoso North, Southwestern Nigeria *Journal of Environment and Earth Science*.3 (14): 84-102

Olsen, S., Watanabe, F. S. and Bowman, R. A. (1983): Evaluation of fertilizer phosphate residues by plant uptake and extractable phosphorus. *Soil Science Society of American Journal.* 47:952–958

Paudel,S and Sah, J.P. (2003): Physiochemical characteristics of soil in tropical Sal (Shorea robusta Gaertn.forests in Eastern Nepal. Himalayan Journal of Sciences 1(2):106-110

Robinson, D.A., Panagos, P. and Borrelli, P. (2017): Soil natural capital in Europe; a framework for state and change assessment. Scientific. Reports. 7:6706-6715.

Sanwo S. K, Ige P. O, Sosanya O. S and Ogunlaye O. G. (2015): Tree species diversity and forest stand dynamic intropical rain forest in southern Nigeria, *Malaysian applied biology*, 44 (2):65-73.

Six, J., Conant, R.T., Paul, E.A. and Paustian, K (2002). Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. *Plant Soil*, 241, 155–176

Sparling, G.P., Whale, K.W. and Ramsay, A. J. (1985): Quantifying the contribution from the soil microbial biomass to the extractable P levels of fresh and air dried soils. *Australian Journal of Soil Resources*, 23:613–621. doi:10.1071/SR9850613

Stanford, G. and Smith, S. J. (1978): Oxidative release of potentially mineralizable soil nitrogen by acid permanganate extraction. *Soil Science* 126:210–218

Tsui, C.C.; Chen, Z.S.; Hsieh, C.F (2004). Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. *Geoderma*,123, 131–142.

Umali, B.P.; Oliver, D.P.; Forrester, S.; Chittleborough, D.J.; Hutson, J.L.; Kookana, R.S.; Ostendorf, B (2012 . The effect of terrain and management on the spatial variability of soil properties in an apple orchard. *Catenary*, 93:38–48.

USDA (1998). Soil electrical conductivity. United State Department of Agriculture. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053280.pdf retrieved on 3rd of January, 2021

Ushio, M., Kitayama, K and Balser, T.C (2010). Tree species effects on soil enzyme activities through effects on soil physicochemical and microbial properties in a tropical montane forest on Mt. Kinabalu, Borneo. *Pedobiologia* 53 : 227–233

Walkley, A and Black, I.A (1934). An Examination of the Digestrates. Method for Determining Soil Organic Matter and Propose Modification of the Chronic Acid Titration Method. *Soil Science.*, 37: 29-38.

Wang, C.K and Yang,. JY (2007) Rhizospheric and heterotrophic components of soil respiration in six Chinese temperate forests. *Global Change and Biology* 13:123–131. doi:10.1111/j.1365-2486.2006.01291.x

Yang K, Zhu J, Zhang M, Yan Q, Sun OJ (2010) Soil microbial biomass carbon and nitrogen in forest ecosystems of Northeast China: a comparison between natural secondary forest and larch plantation. *Journal of Plant Ecology* 3:175–182. doi:10.1093/jpe/rtq022

Yimer, F.; Ledin, S.; Abdelkadir, A (2006). Soil property variations in relation to topographic aspect and vegetation community in the south-eastern highlands of Ethiopia. Forestry. *Ecology and Management*. 232: 90–99.

Zhao, D., Li, F and Wang, R (2012). Soil inorganic nitrogen and microbial biomass carbon and \
nitrogen under pine plantations in Zhanggutai sandy soil, China. *Acta Ecological Sinica* \
32:144–149