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PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN GAMBARI FOREST RESERVE NEAR IBADAN, SOUTH WESTERN NIGERIA.

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ABSTRACT

The different features of soil greatly affect the flora and vegetative diversity of a forest. The physical and chemical characteristics of soils in Onigambari Forest Reserve were evaluated to assess the fertility and productivity status of the soils. Fifteen soil samples collected from different sample locations were analyzed for soil texture (sand, silt and clay), bulk density, porosity, pH, organic matter, total nitrogen, available phosphorus, exchangeable bases (Na, K, Ca and Mg) and available micronutrients (Zn, Cu, Fe and Mn). Texturally, the studied soils were loamy sand and sandy loam with percentage of sands (71.2-84.2 %), silts (7.4-10.4 %) and clay (6.4-19.4 %). The bulk density of the soils was 1.61-1.83 % while the porosity of the soils ranged from 35.2-44.1 %. The slightly acidic to neutral soil pH (5.90 - 6.60) and medium organic matter content (1.68 -2.60 %) suggest adequate level of soil nutrients. The soils had high total nitrogen (0.35 -0.65 %) and available phosphorus contents between 10.98 and 18.22mg/kg.

Keywords: Forest, impact, physicochemical properties, productivity, soil

INTRODUCTION

The major ecological role of soils in forest and natural environment cannot be overemphasized. Soils are significantly affected by geologic and geomorphologic factors (water, wind, temperature change, gravity chemical interaction. topography, vegetation, living organism and pressure differences) (Boul, 1990). Different characteristics of soil such as depth, consistency, temperature, nutrient contents, moisture content, permeability, porosity etc., can greatly influence the nature of vegetation that grows on them (Boyle and Powers, 2013). The physical, chemical and biological processes sustained by soil make it a dynamic zone, consisting of inorganic (rocks) and organic particles (plant and animals remains), liquid (water and chemicals in solution) and gaseous substances (Isah et al., 2014)

The relationship between trees and soil is of importance since they are dependent on each other and on the environment as a whole (FAO, 2015). The support, nutrients and water needed by trees to grow is provided by soil; while trees and other plants are important factors in the formation and enrichment of soil (FAO, 2015).

The biological nitrogen fixation, phosphorus solubilization and decomposition of organic matter in rhizosphere and non-rhizosphere zones of plants increases soil organic matter, improving soil structure and nutrient cycling of soils (Voroney, 2007; Schoenholtz et al., 2000). Likewise, the gathering of nutrients by different tree species as well as their potential to return these nutrients into the soils can cause variations in soil properties (Rawat, 2005).

The regular removal of vegetation through deforestation for farming and other human activities decreases the vegetation cover thereby leading to soil degradation by erosion processes especially in areas with hilly topography (Amonum et al., 2019). It may also result into water logging which may in turn cause leaching of nutrients under the plant's root zone and volatilization, making the soil deficient in some nutrients (Olujobi, 2016). Therefore, sustainability of natural forest and environment depend largely on consistent monitoring of soil quality. Thus, this study investigated the physiochemical properties of soil within the natural forest ecosystem to elucidate the fertility and productivity status of the soil in Gambari Forest Reserve.

MATERIALS AND METHOD

Study Location

The study area, Gambari Forest Reserve lies within latitude 7˚ 23'N and longitude 3˚ 33'E, and covers an area of 11,618 hectares, between the river Ona on the west and on the eastern part of the main road from Ibadan to Ijebu-Ode (Figure 1). The average altitude of the Reserve falls between 122 m to 152 m (asl.) and its topography is more or less undulating. It has an annual rainfall of 1592.3 mm with a relative humidity of 78 – 84.5% and a mean temperature of 26.4˚C (FRIN, 2013).

The soil is of the ferruginous tropical type. The reserve has been reduced to secondary high forest dominated by trees such as *Mansonia altissima*, *Triplochiton scleroxylon*, *Terminalia superba*, *Celtis zenkeri*, *Sterculia* spp., *Terminalia ivorensis* and *Cola* spp*.*, *Tectona grandis* and *Gmelina arborea* (Jayeoba et al., 2013). Geologically, the study area is underlain by Basement Complex rocks of southwestern Nigeria. They comprise of igneous and metamorphic units such as migmatite-gneiss complex, older granite and meta sediments rocks (Akintola, 2014).

Soil Sampling, Collection and Preparation

Fifteen composite soil samples were collected randomly from different locations (Figure 1) at the depth of 0-20 cm using auger. Bulk soil samples were taken into polythene bags and labelled accordingly. The collected soil samples were air dried, gently crushed and sieved through 2 mm mesh for laboratory analysis. The undisturbed soil samples were collected using core cutters and sealed immediately on both edges with candle wax melted on the field to prevent loss of moisture.

Laboratory Analysis

The laboratory analysis carried out on the soil samples included both physical (particle size distribution, bulk density and soil porosity tests) and chemical analyses (pH, organic matter content, total nitrogen, available phosphorus, Na, K, Ca, Mg. Zn, Cu, Fe and Mn). Size distribution test was carried out using hydrometer method of Brown (2003), the bulk density of the soils was determined by drying the undisturbed core samples to a constant weight at 105^{o}C and dividing the oven dried weight of the samples by its volume (Blake and Hartge, 1986) and the porosity of the soil was determined by assuming that the particle density of the soil is 2.65 g/cm^3 (Hao et al., 2008). The pH of the soil samples was determined using electrode pH meter (PCE-228) in water-soil solution (1:1), 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 and available phosphorus were determined by micro-kjeldhal digestion-distillation methods (Bramner, 1965) and electrophotometer method (Bray and Kurtz, 1945). 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 (AAS, MEDTECH). Analysis of Zn, Cu, Fe and Mn were analyzed using atomic absorption spectrophotometer (AAS).

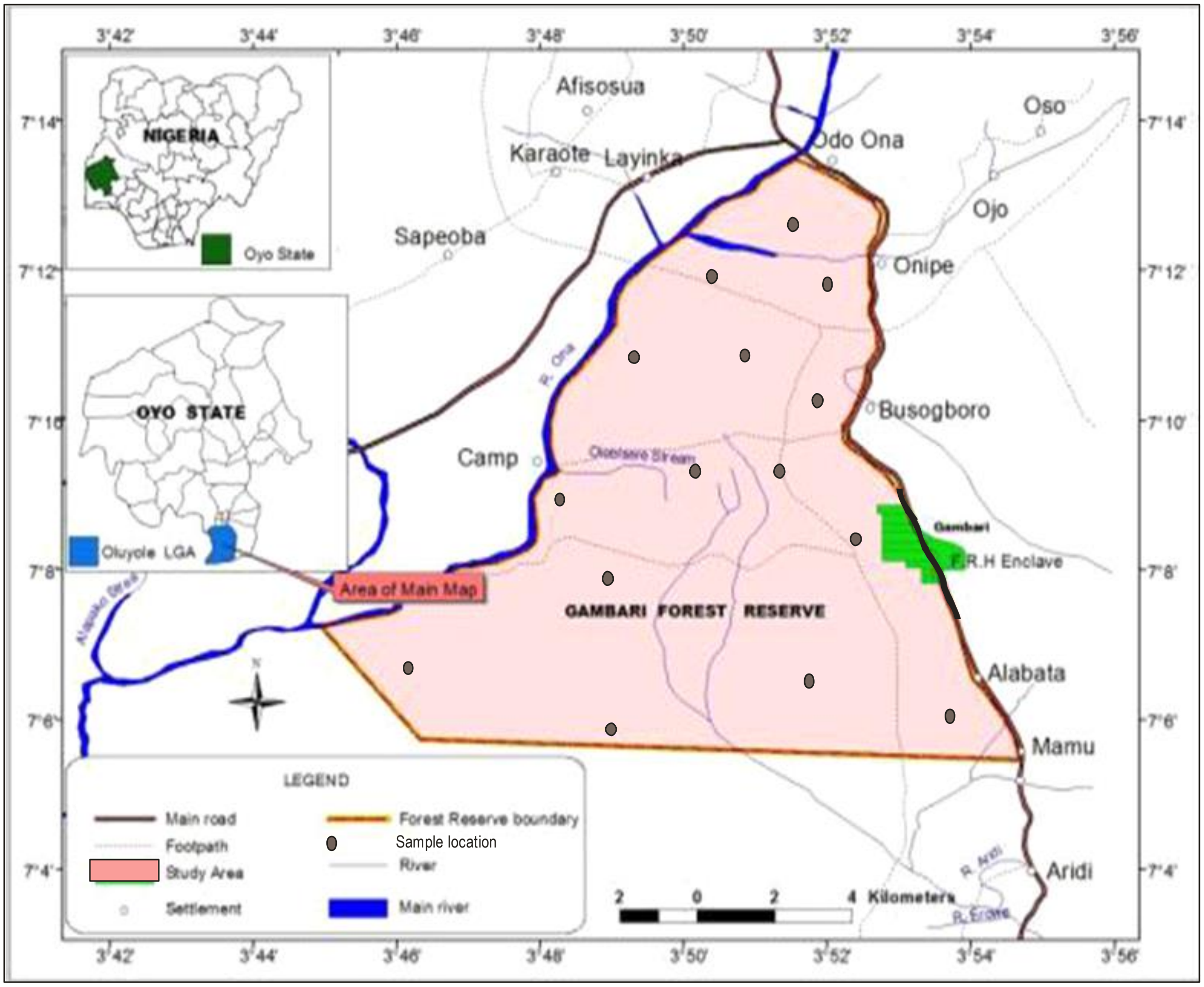

Figure 1: Location map of the study Area (Modified after Jayeoba *et al*, 2013)

Data Analysis

Data obtained from the laboratory was subjected to descriptive statistics using SPSS (version 20). Data was also analyzed using Pearson correlation to show the relationship between the determined parameters.

RESULTS AND DISCUSSION

Physical Properties of the Soil.

The physical properties of soil such as soil texture, bulk density and porosity as pointed out by Nelofer et al. (2016) are predominantly important in determining the ability of the soil for saturation of root, water holding, movement of air, lateral and vertical movement of water into the soil as well as the uptake of water by plants. These in turn are important properties in soil productivity and fertility. The particle size distribution characteristics of the soil showed that sand had the highest percentage value ranging from 71.20 to 84.20 %. While silt had the lowest value ranging from 7.50 to 10.40 % (Table1). Texturally, the studied soils were loamy sand and sandy loam (Table 1).

Tete-Mensah (1993) reported that soils with loose particles such as sand results into a single grain structure while those that are clayey rich with fine grained particles usually become firm (hard ped), impermeable for water and impede penetration of plant roots. Izwaida et al. (2015) reported significant importance of clay in formation of organic matter and its capacity to retain the nutrients in the soil as well as influencing the nutrient level of the soil. According to Fisher and Binkley (2000) the main difference in the soil texture is the surface areas of different particle sizes which affect water potential, organic matter binding cation exchange and overall biotic activity. Therefore, the texture of the soil has great influence on the development of soil aggregates.

Soil structure another important factor for plant growth according to is developed through help of soil biota such as earthworms and microbes which in turn creates openings for water, entrance for air, secretes sugars and glues which can bewilderment silt and clay particles together to form aggregates (Chinevu et al., 2013). Thus, the appreciable amounts of silt and clay in the studied soils suggest that the soil from Gambari Forest Reserve, in the studied areas had a good structure and stable soil aggregates for plant growth. The sandy nature of the soils may be due to the underlying nature of the rocks through which the soils are formed.

In this study, a higher porosity and lower bulk density was noted which conforms with the relationship between the two factors as observed by Blake and Hartge (1986). This may be attributed to the appreciable amount of organic matter in the soil.

Table 1: Values of Determined Physical properties of the studied soils

No of samples	Sand (%)	Silt (%)	Clay (%)	Textural Class	Bulk Density (g/cm^3)	Porosity (%)
1	71.20	9.40	19.40	Sandy loam	1.61	44.10
2	71.40	9.40	19.20	Sandy loam	1.68	43.44
3	81.20	8.40	10.50	Loamy sand	1.81	37.91
4	83.40	10.40	6.20	Loamy sand	1.80	35.20
5	84.20	9.60	6.20	Loamy sand	1.83	39.86
6	80.60	8.40	11.00	Loamy sand	1.79	41.50
7	73.00	7.50	19.50	Sandy loam	1.75	42.75
8	72.80	9.20	18.00	Sandy loam	1.66	43.80
9	75.70	9.30	15.00	Sandy loam	1.76	42.61
10	72.90	8.80	18.30	Sandy loam	1.69	43.56
11	82.20	9.10	9.70	Loamy sand	1.82	38.89
12	75.20	10.37	14.43	Sandy loam	1.64	44.00
13	71.31	9.22	19.47	Sandy loam	1.72	42.98
14	76.35	8.96	15.69	Sandy loam	1.78	42.10
15	78.03	7.57	14.40	Sandy loam	1.77	41.90
Mean	76.62 ± 1.63	9.04 ± 0.25	14.45 ± 1.71		1.74 ± 0.02	41.67 ± 0.86

Chemical Properties of the Soil

i. Soil pH, Organic matter, Total Nitrogen and Available Phosphorus

The pH of the studied soils ranged from 5.90 to 6.60 (Table 2). The soil can be said to be slightly acidic to neutral and this range provides the best growing condition and influences the uptake of nutrients by plants (Suleiman et al., 2017). Soil organic matter content is the rich-mineral constituents in the soils that allows development and growth of plants. It has an important function in soil texture, water retention and contributes immensely to soil nitrogen, phosphorus, sulphur, cation capacity and exchangeable cation (Akintola, 2014). The organic matter of the studied soil ranged between 1.68 and 2.60 % (Table 2). The significant amount of organic matter content recorded in the soils could be ascribed to the decomposition of plant remains from dead soil macrofauna and micro-organisms in the reserves. The total nitrogen content in the soils ranged from 0.35 to 0.66 %, while the values of available phosphorus in the soil were between 10.92 and 18.22 % (Table 2). The high values of total nitrogen (TN) and available phosphorus (AP) may be attributed to high content of organic matter in the soil (Jimoh, 2015; Aliyu et al., 2016). This may also be credited to their occurrence in organic matter combination with organic carbon (Suleiman et al., 2017).

ii. Exchangeable Cations (Na, K, Ca and Mg)

The values of exchangeable cations in the studied soils were Na (0.09 -0.16 Cmol/kg), K (0.12 -0.26 Cmol/kg), Ca (0.61-0.98 Cmol/kg) and Mg (0.19-0.24 Cmol/kg) (Table 2). Generally, the relatively low values of exchangeable cations may be ascribed to soil nutrient losses through anthropogenic activities such as cultivation, harvesting or climatic factors leading to leaching that can prompt mobilization and immobilization of these cations (Isah et al, 2014; Anderson et al., 2017; Suleiman et al., 2017).

iii. Micronutrients (Fe, Zn, Cu and Mn)

The mean values of the micronutrients determined in the soils followed a decreasing order as Fe > Mn > Zn > Cu (Table 2). Low values of standard deviation of these elements observed in the soils is a reflection of low variability in geochemical characterization of the soil (Kelepertzis, 2014). It was observed that the values were within the recommended standard values for normal soils as given by Kabata-pendias (2013).

Table 2. Descriptive statistical values of chemical properties of the studied soils

	Descriptive Statistics				
Parameters	Minimum	Maximum	Mean	Standard Deviation	Variance
pH	5.90	6.60	6.16 ± 0.73	0.26	0.054
OC (%)	0.98	1.51	1.20 ± 0.66	0.18	0.03
OMC (%)	1.68	2.60	2.07 ±0.10	0.30	0.01
Total N (%)	0.35	0.66	0.47 ± 0.04	0.12	0.02
Available P (%)	10.92	18.22	14.74 ± 0.88	2.79	7.80
Na (Cmol/kg)	0.09	0.16	0.12 ± 0.01	0.02	0.00
K (Cmol/kg)	0.12	0.26	0.19 ±0.02	0.05	0.00
Ca (Cmol/kg)	0.61	0.98	0.79 ± 0.05	0.14	0.02
Mg (Cmol/kg)	0.19	0.24	0.21 ± 0.01	0.02	0.00
Fe (mg/kg)	26.88	36.61	32.83 ±1.04	3.29	10.82
Zn (mg/kg)	7.88	9.36	8.71 ± 0.17	0.53	0.28
Cu (mg/kg)	2.55	3.98	3.23 ± 0.14	0.44	0.20
Mn (mg/kg)	74.52	83.87	78.43 ± 1	3.18	10.08

OC: Organic Carbon; OMC: Organic matter content; TN: Total nitrogen; AP; Available phosphorus

Correlation Analysis

Abdul (2017) stated that correlation coefficients whose values are between 0.9 and 1.00 can be rated as very highly correlated, values between 0.7 and 0.9 as highly correlated, values between 0.5 to 0.70 as moderately correlated, values between 0.25 and 0.50 as low correlation while values less than 0.2 have little if any (linear) correlation.

Significant correlation ($P \leq 0.05$) was observed among some of the determined parameters in the soil samples (Table 3). A linear relationship was observed between sand, clay (0.99) and Fe (0.56). This means that as percentage of sand increases, the clay content and concentration of iron in the sampled soil also increases. Low negative correlation existed between silt and clay (-0.41), Porosity (-0.41), pH (-0.31), total nitrogen (-0.29), K (-0.36), Ca (-0.35), Mg (-0.25) and Mn (-0.34). While positive correlation was observed between silt and Zn (0.25); Cu (0.40). Significantly positive correlation was observed between silt and bulk density (0.58), organic carbon (0.56) and organic matter content (0.55).

Bulk density was moderate to highly negative and significantly correlated with porosity organic carbon (0.95), organic matter content (0.95), total nitrogen (0.65), (-0.79), available phosphorus (0.59), Ca (0.68,), Cu (0.59) and Mn (-0.55) but low and negatively correlated with pH (-0.39), Na (-0.42) and Fe (-0.38). Porosity was strongly positive and significantly correlated with organic carbon (0.92), organic matter content (0.92) and; moderately positive and significantly correlated with pH (0.56), total nitrogen (0.62), available phosphorus (0.69), K (0.69), Ca (0.60), Cu (0.59) and Mn (0.55). correlated with total nitrogen (0.71), available phosphorus (0.71), K (0.70), Ca (0.75), Cu (0.67) and Fe (0.58) but low to moderately and negatively correlated with Na (-0.41) and Mn (-0.51).

Total nitrogen was strong to moderately positive and significantly correlated with Ca (0.96), available phosphorus (0.85), K (0.75) and Na (0.58); low and positively correlated with Fe (0.39), Mg (0.32), Zn (0.35) and Mn (0.35) but negatively correlated with Cu (-0.36). Available phosphorus was strong to moderately, positively and significantly correlated with Ca (0.89), K (0.84) and Fe

(0.67), moderate and positively correlated with Mn (0.77), low and positively correlated with Mg (0.39) but negatively and significantly correlated with Cu (-0.58). Available phosphorus was strong to moderately, positively and significantly correlated with Ca (0.89), K (0.84) and Fe (0.67), moderate and positively correlated with Mn (0.77), low and positively correlated with Mg (0.39) but negatively and significantly correlated with Cu (-0.58).

Soil pH strongly influences soil processes such as nitrogen cycling by affecting the soil chemical, physical and biological processes (Anderson et al., 2018). The relationship soil of organic carbon (OC) and organic matter (SOM) with other determined parameters in the studied soils conform with the reports of previous researchers (Shaver et al., 2003; Plante et al., 2006; Najmadeen et al., 2010) that organic carbon and soil organic matter correlate with total nitrogen, available phosphorus, exchangeable cations and micronutrients, thus indicating them as important soil nutrient. It has been shown in this study that as soil organic matter content increased, the other determined parameters in this study also increased. Thus, soil organic matter has a significant influence on physical and chemical factors that affect biological activity (Jalal and Ahmad, 2014).

Table 3: Pearson Correlation coefficients of the determined parameters in the soil samples

Parameters	Parameters																	
	Sand	Silt	Clay	BD	P	pH	OC	OMC	TN	AP	Na	K	Ca	Mg	Fe	Zn	Cu	Mn
Sand	1	0.26	0.99*	0.08	0.33	0.02	-0.15	-0.13	-0.23	0.10	0.06	-0.04	-0.21	0.22	0.56*	0.15	0.23	0.23
Silt		1	-0.40	0.58*	-0.41	-0.31	0.56*	0.55*	-0.29	-0.01	-0.07	-0.36	-0.35	-0.23	-0.14	0.25	0.40	-0.34
Clay			1	0.17	-0.25	0.06	0.05	0.27	-0.96	-0.49	-0.05	-0.09	0.25	-0.17	-0.51	-0.18	0.16	-0.17
BD				1	-0.79*	-0.39	-0.95*	-0.95*	-0.65*	-0.59*	-0.42	-0.60*	-0.68*	-0.10	-0.38	-0.06	-0.59*	-0.55*
P					1	0.56*	0.92*	0.92*	0.62*	0.69*	0.19	0.69*	0.68*	-0.10	-0.38	-0.06	0.59*	-0.55*
pH						1	0.53	0.54	0.87*	0.76*	0.48	0.79*	0.84*	0.49	0.56*	0.24	0.29	0.28
OC							1	1.00*	0.69*	0.69*	-0.39	0.67*	0.73*	-0.20	0.55*	-0.16	0.67*	-0.51
OMC								1	0.71*	0.71*	-0.41	0.70*	0.75*	-0.22	0.58*	-0.15	0.68*	-0.54
TN									1	0.85*	0.56*	0.79*	0.96*	0.32	0.39	0.35	0.36	0.35
AP										1	0.51	0.84*	0.89*	0.39	0.67*	0.27	0.58*	0.77
Na											1	0.30	0.47	0.08	0.33	-0.14	-0.05	0.87*
K												1	0.85*	0.72*	0.72*	0.11	0.62*	0.18
Ca													1	0.36	0.44	0.22	0.56*	0.28
Mg														1	0.64*	0.09	-0.36	0.07
Fe															1	0.03	0.60*	0.38
Zn																1	0.06	-0.16
Cu																	1	-0.16
Mn																		1

Corelation is significant at $P \leq 0.05$
Values with * are values for significant pair
BD: Bulk density; P: Porosity; OC: Organic Carbon; OMC: Organic matter content; TN: Total nitrogen; AP; Available phosphorus

CONCLUSION

The study showed that soil texture is one of the most important factors influencing the physical and chemical properties of the soil. The relationships soil of organic carbon (OC) and organic matter (SOM) with other determined parameters in the studied soils indicated them as important soil nutrients. Soil physical and chemical properties were the dominant factors influencing the extent of decomposition process. Thus, the forest reserve serves as protection for the soil as well as promoting the fertility and productivity of the soils to support a flourishing vegetation types in the area.

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