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Evaluation of some heavy metals and physico-chemical properties of soil under two sampling depths in Gambari Forest Reserve (GFR), Ibadan, Oyo State, Nigeria.

Evaluación de algunos metales pesados y propiedades fisicoquímicas del suelo bajo dos profundidades de muestreo en la Reserva Forestal de Gambari (GFR), Ibadan, Estado de Oyo, Nigeria.

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RESUMEN

This study was carried out with the aim of determined the soil depth variations in heavy metals and some physico-chemical properties of soil depths sampled in Gambari Forest Reserve (GFR). It was examined with the purpose of evaluating the environmental impact of human activities on the Forest Reserve. Soil samples were collected randomly from eight plots within the forest at two different depth of 0-15 and 0-30 cm with the aid of soil auger. Systematic sampling design was used to lay two straight line transects, each of 1000 m long and separated by 500 m, in the reserve. Four Temporary Sample Plots (TSP) of size 50 m×50 m were laid along each transect at 250 m interval. Furthermore, a 6 × 6 m subplot was laid out at the centre of each plot. Samples of about 500 g each were collected in plastic bags and taken to the laboratory for analysis. The physico-chemical properties were evaluated using standard methods, while metal contents were conducted with flame atomic absorption spectrophotometer following wet acid digestion. Descriptive and inferential statistics were used for data analysis. The content of metals (mgkg^{-1}) gave the ranges: 3.02-5.92 Cd, 8.69-14.25 Cr, 1.39-1.67 Cu, 5.01-6.83 Mn, 13.37-14.25 Ni, 3.69-5.89 Pb and 1.59-1.75 Zn, with a variation pattern in order: Ni > Cr > Mn > Pb > Cd > Zn > Cu in both soil depths. With the exception of Cadmium, the degree of pollution varied with, by values that were far less than the upper tolerable limits set by Food and Agriculture Organization and World Health Organization for agricultural soils. Results show that sand had the highest % in soil of the area (92.34). Bulk densities were at ranges of (1.43, 1.45 and 1.23g/cm^3) at the depth of 0-15 and 15-30, respectively. The textural classification for each depth of soil was Sandy-loam with percentages of sand (89.9-86.0), silts (10.94-4.41) and clay (5.68-3.03). Considerable spatial variations in contents were observed for all physico-chemical properties in all part of the study sites. GFR is relative nutritious and contain high amount of heavy metals. Therefore, it recommended that reserve should be enriched with tree and properly protected and monitored from encroachment of both human being and animals.

Keywords: Evaluation, Gambari Forest Reserve (GFR), Heavy metals, Physico-chemical Properties, Soil depth.

RESUMEN

Este estudio se llevó a cabo con el objetivo de determinar las variaciones de la profundidad del suelo en metales pesados y algunas propiedades fisicoquímicas de las profundidades del suelo muestreadas en la Reserva Forestal Gambari (GFR). Se examinó con el propósito de evaluar el impacto ambiental de las actividades humanas en la Reserva Forestal. Se recolectaron muestras de suelo al azar de ocho parcelas dentro del bosque a dos profundidades diferentes de 0-15 y 0-30 cm con la ayuda de una barrena de suelo. Se utilizó un diseño de muestreo sistemático para colocar dos transectos en línea recta, cada uno de 1000 m de largo y separados por 500 m, en la reserva. Se colocaron cuatro Parcelas Temporales de Muestra (TSP) de 50 mx 50 m a lo largo de cada transecto con un intervalo de 250 m. Además, se dispuso una subparcela de 6 × 6 m en el centro de cada parcela. Se recogieron muestras de unos 500 g cada una en bolsas de plástico y se llevaron al laboratorio para su análisis. Las propiedades fisicoquímicas se evaluaron utilizando métodos estándar, mientras que los contenidos de metal se realizaron con un espectrofotómetro de absorción atómica de llama después de la digestión con ácido húmedo. Para el análisis de los datos se utilizó estadística descriptiva e inferencial. El contenido de metales (mgkg-1) dio los rangos: 3,02-5,92 Cd, 8,69-14,25 Cr, 1,39-1,67 Cu, 5,01-6,83 Mn, 13,37-14,25 Ni, 3,69-5,89 Pb y 1,59-1,75 Zn, con una patrón de variación en orden: Ni > Cr > Mn > Pb > Cd > Zn > Cu en ambas profundidades del suelo. Con la excepción del cadmio, el grado de contaminación varió con valores que fueron mucho menores que los límites tolerables superiores establecidos por la Organización para la Agricultura y la Alimentación y la Organización Mundial de la Salud para suelos agrícolas. Los resultados muestran que la arena tuvo el mayor % en suelo de la zona (92,34). Las densidades aparentes estaban en rangos de (1,43, 1,45 y 1,23 g/cm3) a la profundidad de 0-15 y 15-30, respectivamente. La clasificación textural para cada profundidad de suelo fue Franco-arenoso con porcentajes de arena (89.9-86.0), limos (10.94-4.41) y arcilla (5.68-3.03). Se observaron variaciones espaciales considerables en los contenidos para todas las propiedades fisicoquímicas en todas las partes de los sitios de estudio. La TFG es relativamente nutritiva y contiene una gran cantidad de metales pesados. Por lo tanto, recomendó que la reserva se enriquezca con árboles y se proteja y controle adecuadamente contra la invasión de seres humanos y animales.

Palabras clave: Evaluación, Reserva Forestal Gambari (RGF), Metales pesados, Propiedades fisicoquímicas, Profundidad del suelo.

INTRODUCTION

Forest soil is one of the major constituents of environment which contains organic matter, moisture content, air and living organisms. Its importance is immeasurable. Soils are affected by climatic, geologic, anthropogenic, chemical interaction and geomorphologic factors (Boul, 1990). The impacts of natural conditions under the influence of permanent vegetation cover over a long period of time lead to the development of the physical property of soil (Salami *et al*., 2020). Physical characteristics of soils may beonits stable properties except altered by human activities such as agricultural and forestry activities. The physical properties of forest soils influence all areas of soil fertility and productivity (Salami *et al*, 2020; Osman, 2013). The interaction of different attributes of forest soil such as biological, physical and chemical controls nutrient availability. Soil attributes can significantly influence the type of plant that grows on them. These attributes include soil depth, moisture content, consistency, permeability, temperature, nutrient contents and porosity (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 three major processes persistent by soil make it an active zone which consisting of inorganic, organic particles, moisture content and chemicals and gaseous substances. The distribution characteristics of mineral elements in both trees and soils are regarded as one of the major factors controlling the tree communities. The interaction between forest soil and tree is major in the system because they depend on one another (FAO, 2015). Forest soil contains nutrients and moisture content needed by plants for growth and development while tree and other plants are vital factors in the formation and soil enrichment (FAO, 2015). The possible impact of logging in rainforest has both environmental and biological consequences. Laurance (2001) noted that old forest can be exposed to colonization; during logging, new forest roads are constructed (Wilkie *et al.*, 2000). Deforestation will reduce the environmental functions of ecosystem. Also, this act will cause climate change and global warming as a result of interference on the ecosystem. These functions include wind break, micro-climate creation, carbon sequestration, erosion and leaching control, air purification and provision of shade during hot season. There is scientific interest concerning the effects of global warming on terrestrial ecosystem as reported by Ranasinghe and Abayasiri (2007) and Verchot (2007). The ability to determine the importance of several soil features in determining productivity has been enormously enhanced by evaluating the physico-chemical characteristics of soil. This study seeks to evaluate the heavy metals and physico-chemical properties of the degraded forest in GFR with a view of understanding the soil status of the study site and planning for better conservation.

MATERIALS AND METHODS

Gambari Forest Reserve (GFR): GFR has a coordinate ranges between latitude 7º 25' and 7º 55' N and longitude 3º 53'and 3º 9' with a total land area of 17,984 hectares which is situated within the rain forest belt of Nigeria (Salami and Akinyele, 2017). The study area is made up of natural rain forest ecosystems and plantation forest. The landscape of the area is undulating, lying at height between 90 m to 140 m above sea level which covers an area of (11,618 hectares) between the river Ona by the west and Ijebu-Ode to the eastern part (Figure 1) (Salami *et al.,* 2016). Salawu (2002), also noted distance between these areas is about 200 m to 500 m and altitude of 147 m depends on the nature of the areas with a total number of people of 600. The yearly rainfall known with the minimum of 1200 mm and maximum of 1300 mm distributing from third to eleventh month of the year. The severe dry season starts from December and ends by February while the humidity is above 80 % and average annual temperature is about 26.4 ºC (Salami and Akinyele, 2017; Larinde and Olasupo, 2011). The reserve is well known with tree species like *Tectonia grandis, Khaya ivorensis* and agricultural crops such as *Theobroma cacao and Manihot esculenta.* Farming is the major occupation of the inhabitants with low hunting activities. These areas are along the same equatorial belt within the study area. GFR is surrounded with the following villages: Akintola, Akinogbun, Amosun, Aba-Igbagbo, Ajibodu, Gbale-Asun, Lagunju, Olonde Ige, Olaya, Onipede, Okeseyi, Salami and Akinyele, (2017).

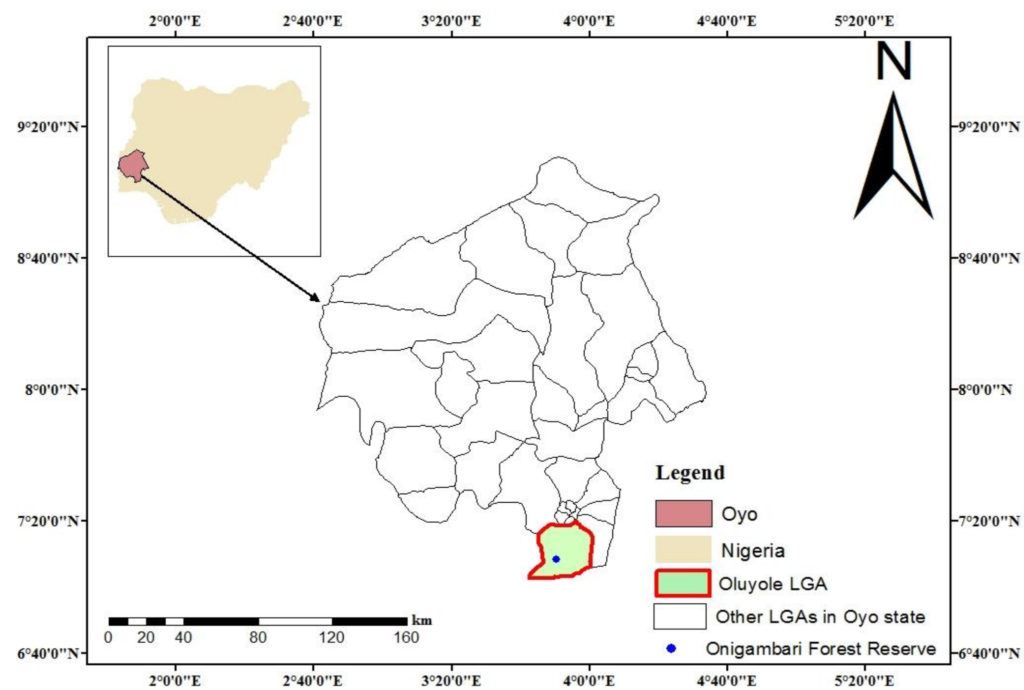

Fig 1. Map of Gambari Forest Reserve

Relief and Soils: The soils are well drained, mature, red, stony and gravely in upper parts of the sequence. The texture of topsoil in the reserve is mainly sandy loam (Salami, 2017). The primary soils of the reserve are Ferrallic which belong to the order of Oxisols. The physical and chemical attributes of the soil vary but display some common attributes. It is well known with well drained, bright red to brown in colour and dominated by the Kaolinite nature of clay. They are commonly occurring in loamy or clayey but often sandy in the superficial layers usually poor in bases. The clay content is very rich in alumina and poor in silica. The crop productivity is greater than 2500 kgm^{-2} per annum (Salami and Akinyele, 2018)

Vegetation: The composition and structural information of the forest have provided by many scientists in the lowland rainforest (Salami, 2017; Richard, 1996 and Bada, 1984). Among the features of the forest provided are plants, climbers, epiphytes, shrubs and tree of the sizes. There is some diversity of plants and animals that have not been covered and documented. Etukudo (2000) noted that there are great varieties of trees in few hectares of the forest than the entire vegetation.

Sample Plots Demarcation: Systematic sampling design (line transect) was applied for plots layout in the study site. Two line transects with a distance of 500 m between were laid at the center of the forest. Sample plots of equal size (50 × 50 m) were laid in alternate direction along each transect at 250 m interval and thus summing up to 4 sample plots per transect and a total of 8 sample plots per study site (Figure 2). This design was applied to ensure that the study site is relatively covered. A sum of 20,000 m^2 was sampled in the study site. Furthermore, a 6 × 6 m subplot was laid out at the centre of each plot. Samples of soil were collected in all subplots (Salami and Akinyele, 2018; Onyekwelu *et al.*, 2008). According to soil profile classification by Taylor and Francis (2006), three soils samples (at 2 m intervals) was collected from each sample plot at four fixed depths of 0–15 and 15–30 cm using auger. Soil samples from similar depths within each sample plot were thoroughly mixed and composite samples collected. Soil samples for bulk density were collected from 0−15 cm only.

Data collection: Soil samples were taken in each sub plots at two sampling depths within the sample plots across the study area. The samples were analyzed for nutrients status according to (Salami and Akinyele, 2018; Onyekwelu *et al*., 2008). Samples were collected at two different depths: 0-15 cm and 15-30 cm respectively.

Laboratory analyses of soil samples: Soil samples were air-dried and ground in a Wiley mill to pass through a 2-mm sieve. Particle size analysis was done employing hydrometer method, with sodium Hexameta-phosphate as dispersing agent. In expressing soil particle size fractions, the USDA particle size classification system were adopted (Soil Survey Staff, 2003). Core cylinder samples were dried for 2 days at 105°C and bulk density was evaluated as the ratio of oven-dry weight of soil to cylinder volume. pH of the soil was assessed using a digital pH meter in 1:2 soil/water solutions. Organic matter was calculated by first determining organic carbon using method and then multiplying the result by 1.724. Extract for available P was prepared with ammonium fluoride and P was determined using molybdenum blue method (Taylor and Francis, 2006). Total N was determined using micro-

Kjeldahl method with selenium catalyst (Bremner, 1965). For determination of exchangeable Ca, Mg, K and Na, soil samples were first leached with 1 N ammonium acetate solution (pH = 7.0). Exchangeable Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) while exchangeable Na and K were determined by digital flame photometry.

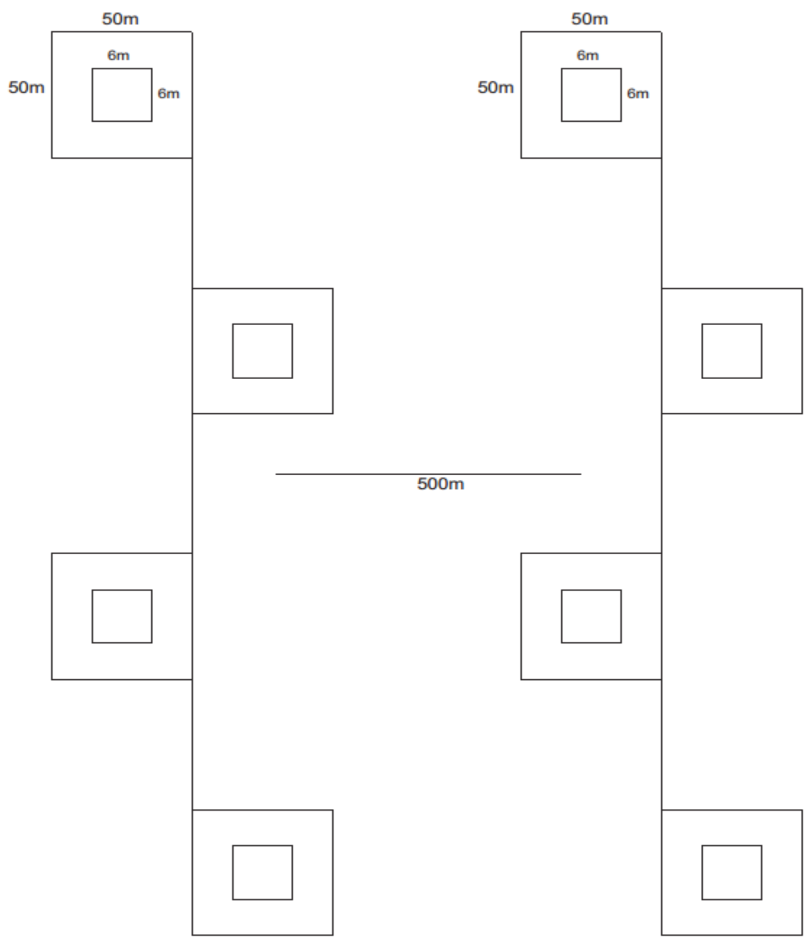

Fig. 2: Plot layout with systematic line transects sampling technique

Data Analysis: Data obtained from the laboratory were subjected to descriptive statistics using SPSS (version 20). Data were analyzed using Pearson correlation to show the relationship between the determined physical and chemical properties while T test was used to compare between depths

RESULTS AND DISCUSSION

Physico-Chemical properties of sampling depths: The physico-chemical properties of soil samples of the GFR were evaluated. The results are revealed in Table 1. Soil texture is a key property of soil; it denotes particle sizes composing the soil. Soil textural classes express the amount of sand, silt and clay in percentages. In this study, the two sampling depths (0-15 cm and 15-30 cm) (Table 1).

In general, all the soil samples horizons from GFR were predominated by high % sand fractions after that % clay and lastly % silt while the 15-30 cm, was predominated by high % sand fractions after that % silt and last of all % clay. The variation in particle size pattern revealed that these soils were not originated from the natural processes of basic parent substance but from deposited particles from erosion similar process (Ogunwale *et al*., 2019).

The Cation Exchange Capacity (CEC) is the amount of exchangeable cation per unit weight of dry soil. It also plays a major role in fertility of the soil by reason of its link to particle size distribution and on the soil organic matter content (Ogunwale *et al*., 2021). Findings of this study indicated that soils from the forest reserve sites had moderately higher values of CEC ranging from 5.57 to 6.54 Cmolkg^{-1} soil (Table 1). Even though the clay contents at the forest site was much smaller than the silt content, it was probably that a significant portion of exchangeable bases at the forest site existed as a water-soluble form instead of an exchangeable form adsorbed at cation exchange sites. The higher the CEC values and organic matter in the vicinity of the forestry field could help woody plants in picking up nutrients more easily (Ogunwale *et al.,* 2021).

All the soil samples had elevated Ca^{2+} values more than 0.30 Cmolkg^{-1} soil which is regarded as lower value for productive soils (Ogunwale *et al.*, 2021). Exchangeable K^+ ranged from 0.57 Cmol/kg soil to 0.64 Cmol/kg soil in forest reserve soils for the two depths; these values were beyond 0.15 Cmolkg^{-1}soil which is given as the prescribed level of exchangeable K^+ in soils (Ogunwale *et al.*, 2021). The interpretation of these is that the soil was abundant in nutrients; an evidence of healthy produce ability outside of any input of inorganic fertilizers.

The presence of organic carbon increases the cation exchange capacity of a given soil and aids the soil to retain nutrients that could be absorbed by plants (Ogunwale *et al.,* 2021). Values of Total Organic Carbons (TOCs) in the soils under study for 0-15 cm and 15-30 cm presented in Table 1 varied from 1.44 to 1.49%, respectively. The TOC values could be ranked as moderate to high, derived from the grouping of soil %TOC prescribed by Weil and Brandy (2017) signifying a likelihood of higher holding of nutrients within the soil. The moderately high quantity of TOC of the poultry soils is indicative of deterioration or occurrence of degradable and compostable wastes (Ogunwale *et al.,* 2021).

The organic matter content of GFR soil sampling depths in the present work are revealed in Table 1. The values varied from 2.48 to 2.57% .The soil organic matter was moderately high on the categorization of soil % Organic Matter (OM) recommended by FAO/WHO (2011) in the present work for all soil samples signifying moderate retention of solubilized metals within the soil. There was a variation in % Organic Matter (OM) across the soil horizons. It indicates that the GFR soil does not need any inorganic fertilizer in order to support agricultural crop production as at the time of sample collection.

The percent Total Nitrogen (%TN) value of forest reserve soils varied from 0.12 to 0.13%. This pattern was formerly be dependent on Adepetu (1986), who reported that percentage nitrogen in the topsoil of southwestern Nigeria is typically between 0.10% and 0.25% in derived savannah zones. Ogunwale *et al*. (2021), expressed that nitrogen value is an indicator of biomass and they are responsible for the general renewal of microbial plants. Generally, if it is lower than 0.20%, it will be good enough to satisfy the N preconditions of micro flora that decay the remains (Ogunwale *et al.,* 2021). In line with Ogunwale *et al*. (2021), the low levels of nitrogen values demonstrated high disintegration and effective mineralization activity at the soil site. In the present work, percentage nitrogen in soil was higher in the soil depth of 0-15 cm as a result of the oxidation of dead plant organic material which was more on the top soil stratum.

Ogunwale *et al.* (2021), ascribed the high contents of nitrogen to discharge from the decomposition of a great number of soil organism in the derived savannah ecosystem. The soil organism may be an abundant source of nitrogen as revealed by regular breakdown by earthworm which build cast on the soil. Fragmenting leaves by earthworm may be risen the nutritional value of the substrate detritus (Ogunwale *et al*., 2021).

The forest reserve site contained higher contents of AP varying from 5.26 to 5.26mgkg^{-1} (Table 1). This could be ascribed to the availability of high quantity of organic matter and plants decay at the forest reserve sites (Ogunwale *et al*., 2021). The high content of phosphorous enhances good growth of timber species as was noted. All the soil samples had available P contents more than 5 mg/kg which is considered as suitable for crop growing (FAO/WHO, 2011).

Mean Heavy Metals Concentrations of Forest Reserve Soils Depths: The total contents of Cd, Cr, Cu, Mn, Ni, Pb and Zn in the forest reserve soils depths samples are revealed in Table 1. Though the concentration ranges varies from one depth sample to another but majority of the concentrations are below FAO/WHO limits for agricultural soil.

The values of Cd ranged from 3.02 –5.92 mg/kg. The highest Cd concentrations (3.02 and 5.92 mg/kg) were found at 15-30 cm and 0-15 cm soil depths. All the soil samples were considered contaminated, as the Cd concentration was above the FAO/WHO safe limit of 3mgkg^{-1}. The elevated levels of Cd in the soil sampled might be due to contaminant in soil and logging truck emission, forest clearance for farming and building supplies as Cd occurs in fuel as oil/lubricants. The logging truck activity is so high around the study sites that the air pollution could convert to soil pollution in short-term. The introduction of Cd into the food chain may affect human health and may cause osteoporosis, anaemia, eosinophilia, emphysema, and renal tubular damage. Long-term cadmium toxicity can produce Itai-Itai disease, in which individuals suffer from bone fractures, severe pain, proteinuria, and severe osteomalacia (Ogunwale *et al*., 2021).

The concentration range of Cr was found to be 8.69 to 14.25mgkg^{-1} with the highest concentration recorded in 0-15 cm and the lowest in 15-30 cm soil depths. All the results obtained are below FAO/WHO safe limits.

The concentration of Cu in the examined soil samples ranged from 1.59 –1.67 mg/kg across the samples and below the FAO/WHO safe limits of 100 mgkg^{-1}. This is lower than the findings of Ogunwale *et al*. (2021), who reported Cu concentrations of 31.55 ± 0.95 mgkg^{-1}for Osun poultry farm soil.

Maximum concentration of Mn of 6.83 mg/kg was found in 0-15 cm and lowest concentration of 5.01 mg/kg was found in 15-30 cm. Manganese obtained was below the FAO/WHO safe limits. The range of values of Mn reported for Spanish soil (181-366 mg/kg) was much higher than the levels detected in the present study. Harvesting operations, shifting cultivation, forest fires and brake linings might have added to Mn concentrations found in this present work, since Mn and other metals have been expressed to be present in these activities particularly as there is nonappearance of industrial activity in the study area. It could also be as a result of substituting Pb with Mn in petrol additives.

In the case of Ni, levels identified ranged from 13.37 to 14.25 mg/kg and across the samples below the FAO/WHO safe limits of 100 mg/kg. Environmental anthropogenic sources of Ni like land clearing for farming, logging, fire-wood collection, deposition of wood waste, animal wastes and forest wild fire might have contributed to the Ni values detected in this investigation.

The concentration of Pb in the assayed samples varied from 5.69 to 5.89 mg/kg. In this research, samples taken from 0-15 cm had the highest concentrations of Pb. The small amount detected in all the soil depths could be by virtue of garbage disposal, discarded batteries, and activities around the forest reserve, burning and corrosion of other Pb bearing materials. Lead levels found from this study are lower than those reported in such places as the US, China, Poland, India and Ethiopia. This possibly revealed the compliance of the petrochemical industry in Nigeria to produce non-leaded fuel.

Zinc concentrations in this analysis ranged from 1.59 to 1.75 mg/kg. Zinc levels in this studied are within the background levels for agricultural soil (Brady and Weil, 2017) in both soil depths. Toxic levels of Cd may restrain Zn absorption (Ogunwale *et al*., 2019). In relation to FAO/WHO (2011), natural heavy metals concentrations (mg/kg) of surface soils are: Cd = 3, Cu = 100, Mn = 200, Ni = 75, Pb = 100 and Zn = 300. Comparing these values with 0-15 and 15-30 cm soil depths values obtained in this study, Cd was higher. The results obtained in this study are comparable with some literatures values of similar studies reported previously (Oyekunle *et al.,* 2011; Ogunfowokan *et al.,* 2013; Ogunwale *et al.,* 2021).

Table 1: Mean percentage of Physico-chemical properties of soil at different depths in Gambari Forest Reserve (in Cmol/kg and mg/kg)

Sample	%S	%C	%Si	Ca	Mg	Na	K	CEC	%TOC	%TOM	%TN	Av.P	Cd	Cr	Cu	Mn	Ni	Pb	Zn
0-15 cm	89.92	5.67	4.41	3.29	2.05	0.56	0.64	6.54	1.49	2.57	0.13	5.37	5.92	14.25	1.67	6.83	14.25	5.89	1.75
15-30 cm	88.36	4.49	6.90	2.89	1.59	0.52	0.57	5.57	1.44	2.48	0.12	5.26	3.02	8.69	1.39	5.01	13.37	3.69	1.59

Table 2: Correlation coefficients of Soil Physical properties in Gambari Forest Reserve

Samples %	Sand A	Clay A	Silt A	Sand B	Clay B	Silt B	Sand C	Clay C	Silt C	Sand D	Clay D	Silt D
Sand A	1											
Clay A	0.80*	1										
Silt A	-0.92	-0.90*	1									
Sand B	-0.61*	-0.85*	0.56*	1								
Clay B	0.60*	0.02	-0.43	0.23	1							
Silt B	0.40	0.74*	-0.38	-0.97*	-0.44	1						
Sand C	0.38	0.82*	-0.68*	-0.55*	-0.32	0.53*	1					
Clay C	0.57*	-0.00	-0.43	0.28	1.00	-0.50*	-0.30	1				
Silt C	-0.85*	-0.69	0.94*	0.26	-0.63*	-0.04	-0.53*	-0.65*	1			
Sand D	-0.00	-0.47	0.02	0.79*	0.76*	-0.91*	-0.43	0.80*	-0.31	1		
Clay D	0.10	-0.47	0.03	0.70*	0.85*	-0.84*	-0.59*	0.87*	-0.27	0.96*	1	
Silt D	-0.03	0.48	-0.02	-0.76*	-0.80*	0.89*	0.51	-0.83*	0.30	-0.99*	0.98*	1

Note: Soil depths A: 0-15cm, B: 15-30 cm

Table 3: Correlation coefficients of Soil chemical and metals properties in Gambari Forest Reserve

	Pb	Ca	Mg	Na	K	N	OC	Av. P	Cd	Cr	Ni	Mn	Cu	Zn
Pb	1													
Ca	-0.28	1												
Mg	-0.05	0.39	1											
Na	0.33	0.34	-0.35	1										
K	-0.12	0.54*	-0.08	0.62	1									
N	-0.56*	-0.07	-0.05	-0.19	0.32	1								
OC	-0.32	-0.32	-0.16	0.04	0.03	0.34	1							
Av.P	0.47	-0.09	-0.05	0.10	0.11	-0.11	0.00	1						
Cd	-0.29	0.24	0.06	0.19	0.16	-0.28	0.06	-0.34	1					
Cr	0.00	-0.03	0.16	0.17	0.40	0.04	0.10	-0.04	0.62*	1				
Ni	-0.59*	0.19	0.23	-0.06	0.28	0.27	0.31	-0.56*	0.67*	0.48	1			
Mn	0.11	0.18	0.12	0.41	0.52*	-0.20	0.22	-0.21	0.24	0.38	0.33	1		
Cu	-0.01	0.39	-0.28	0.60*	0.74*	-0.01	-0.10	0.05	0.57*	0.55*	0.38	0.27	1	
Zn	-0.46	0.49	0.43	-0.11	0.13	-0.08	-0.18	-0.40	0.76*	0.52	0.70*	0.01	0.39	1

From the statistical results found, all the heavy metals across the sampling sites were significantly different at $p < 0.05$ which indicates that there is significant association between the overall means of Cd, Cr, Cu, Mn, Ni, Pb and Zn in the forest reserve soil of the study area. Sites revealed no significant effect on difference between group means of the physico-chemical and heavy metals at different depths (Tables 2 and 3). This extrapolates that there is some degree of contribution of these physico-chemical and metals between depths. Inter-elemental association by Pearson Correlation Coefficient, r, and the results for the research area were shown in Tables 2a and 2b. The inter-elemental relationship showed positive correlation between the given studied physico-chemical and metals with the exception of SA with SiA, SB and SC; CA with SiA, SB and SiC; SiA with SC; SB with SiB, SC and SiD; CB with SiC; SiB with SC; CC with SiC; SD with SiD; Pb with %TN and Ni and Av.P with Ni. Table 2b indicated that some interphysico-chemical and heavy metals pairs, SA/CA (r=0.80), SA/CB (r=0.60) and SA/CC (r=0.57), CA/SiB (r=0.74) and CA/SC (r=0.82); SiA/SB (r=0.56) and SiA/SiC (r=0.94); SB/SD (r=0.79) and SB/CD (r=0.70); CB/SD (r=0.76) and CB/CD (r=0.85); SiB/SC (r=0.53) and SiB/SiD (r=0.89); SC/SiD (r=0.51); CC/SD (r=0.80) and CC/CD (r=0.87); SD/CD (r=0.96); CD/SiD (r=0.98); Ca/K (r=0.54); Na/K (r=0.62) and Na/Cu (r=0.60); K/Mn (r=0.52) and K/Cu (r=0.74); Cd/Cr (r=0.62), Cd/Ni (r=0.67), Cd/Cu (r=0.57) and Cd/Zn (r=0.76);Cr/Cu (r=0.55) and Cr/Zn (r=0.52) and Ni/Zn (r=0.70), have strong correlation with each other. On the other hand, pairs such as Pb/Ni (0.47), Ca/Cu (0.39), Na/Mn (r=0.41), K/Cr (0.40) and Cr/Mn (0.38) and Cu/Zn (0.39) have moderate associations. Tables 2a and b also indicated that the elemental pair CD/SD significantly presented the strongest correlation (r=0.98, p<0.01). On the other hand, the pairs of CD/SD and SD/CD were significant at 95% confidence level while the other elemental pairs reveal no significant correlation with each other. The results showed that forest reserve soil contamination by the metals obtained from similar source of pollution which is logging truck. The investigation area with the exemption of the Idi Ayunre Sawmill factory had no heavy or major industrial development; it can be extrapolated that the heavy metals analyzed in the forest soil were derived virtually wholly from logging trucks and local industries.

As conclusion an evaluation of Cd, Cr, Cu, Mn, Ni, Pb and Zn, and some physico-chemical properties from the 0-15 cm and 15-30 cm soil depths of GFR in Oyo State was carried out in comparison with the ecological soil guiding principle. The homogeneity of variance in the soil metals and physico-chemical properties of the 0-15 cm and 15-30 cm soil depths of the GFR throughout the study periods indicates similar spatial ecological states of the reserve. The physico-chemical constituents load support permeability of heavy metals from the soil depth. The results also revealed that GFR soils were significantly contaminated with Cd, although most of the heavy metals concentrations were less than the prescribed limit. The soils within the vicinity of the GFR studied are considered largely healthy for forests sustainability and wildlife survival, furthermore, the continuing forestry practices could result in increase in building up of heavy metals in the soil after a while. Hence, foresters should be proactive in guiding against practices that could negatively compromise the health of their practicing ecosystems. Generally, the major factors to heavy metal contents still look to be of man-induced sources together with land use activities. With the purpose of achieving decline soil pollution springing from forestry practices, there is the need for continuous surveillance of Nigerian forest reserve soil to assess their quality status. The work has provided information on the extent of heavy metal pollution in the GFR soils as a way of evaluating the environmental health of the area under study. The study had also contributed to the baseline data on heavy metals contents and soil physic-chemical properties studies in our environment.

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