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PHYSICOCHEMICAL PROPERTIES OF SOILS OF FARAI AND GA'ANDA SACRED FORESTS, ADAMAWA STATE, NIGERIA

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ABSTRACT

This research was conducted to compare soil nutrient status of Farai and Ga'anda sacred forests of Adamawa State, Nigeria. Plot method was used for the data collection were a one-hectare 100m × 100m was marked out. Soil samples were collected from ten (10) auger points within established plots for physicochemical analysis. Student t-test was used to compare results from the two sacred forests. The highest values for soil physical parameters in the sacred forests were Farai; Sand 83.20%; Silt 27.6%; Clay 39.20%; BD 1.6g/cm^3; porosity 50% and WHC was 16%, while that of Ga'anda were Sand 75.20%; Silt 21.6%; Clay 39.20%; BD 1.58g/cm^3; porosity 50% and WHC was 15%. Similarly, the highest values for soil chemical parameters in the two sacred forests were Farai; pH 7.90; EC 0.42dS/m; OC 1.76%; TN 0.30%. AVP 13.76 ppm; Ca2+, Mg2+, Na$^+$, K$^+$, TEB TEA, ECEC and PBS highest values were; 6.40, 3.60, 1.70, 0.56, 10.12, 3.20 and 13.32 Cmol/Kg and 72.83%, while that of Ga'anda were pH 7.60; EC 0.29dS/m; OC 1.17%; TN 0.20%. AVP 12.57 ppm; Ca2+, Mg2+, Na$^+$, K$^+$, TEB TEA, ECEC and PBS highest values were; 6.40, 3.60, 1.00, 0.79, 10.43, 3.20 and 12.54 Cmol/Kg and 89.68% respectively. The Student t-test for the soil parameters between the two forests tested at ($P \leq 0.05$) level of significance showed no significant differences in physical properties. The chemical parameters however showed significant differences only in OC, TN, TEA and PBS. Findings of this study have revealed high levels of some nutrients necessary for tree species flourishing while there were low levels of others. It is thus recommended that conservation of sacred forests particularly in the semi-arid regions of Nigeria should be encouraged as a means to conservation of the soils.

Keywords: Physical and Chemical Properties; Soils; Sacred Forests; Farai; Ga'anda

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INTRODUCTION

Forest soils are composed of the original geologic mineral substrate that has been deposited across the topography of the landscape, acted upon by various biotic organisms, and over time weathered by the climate conditions of the region. The most biologically active portion of any soil is near the surface, where the levels of oxygen and water are most conducive for plant root growth and microorganism activity (Chandy *et al.,* 2014). The uppermost soil layer is most heavily influenced by the incorporation of organic matter – mostly from grass, forb and shrub fine root turnover and decomposition, but also the deposition of woody debris on the soil surface. Soil is a reservoir of nutrients in one form or other and differs from the parent material and among themselves in the morphological, physical, chemical and biological properties (Chandy *et al.*, 2014). It is the loose top layer of the earth's crust composed of weathered rock, minerals and partly decayed organic matter. According to Alan (1993), soil is responsible for anchoring the plants on to the earth's surface, supplying it with water and nutrients required for its growth. Soil physical properties include soil texture, structure, porosity, soil density, drainage and surface hydrology. These properties are very important in influencing what plants can grow on a site and how well they grow. The soil physical properties determine the ease of root penetration, the availability of water and the ease of water absorption by plants, the amount of oxygen and other gases in the soil, and the degree to which water moves both laterally and vertically through the soil.

Plant shed parts of their biomass (litter fall) periodically, which is a key ecological process in terrestrial ecosystems that serves as a linkage between the vegetation and the soil (Vitousek 1984; Lowman 1988; Sayer 2006; Huang *et al.,* 2017; Chakravarty *et al.,* 2019; Zhu *et al.,* 2019). Litter inputs and their decomposition improve the soil structure and function through the soil organic matters and the nutrient pool (Bargali *et al.,* 1993; Yu *et al.,* 2004; Rawat *et al.,* 2010; N'Dri *et al.,* 2018). Litter fall and decomposition also contributes to long term carbon storage, ecological restoration and regeneration dynamics (Watanabe *et al.,* 2013; Campos *et al.,* 2017; Tian *et al.,* 2017). The presence of litter in the forest floor can potentially increase seedling diversity (Molofsky and Augspurger, 1992) and can change plant recruitment rates by creating an insulating layer and reducing soil evaporation and the density of weeds (Facelli and Pickett, 1991).

In many villages in Africa, there is often a huge tree or a small forest rising up in the boundary savanna in which local people perform their cult. Though the sacred forest in Nigeria are biological heritage and a system that has helped to preserve the representative genetic resources existing in the surrounding regions for generations, they are declining in numbers and size rapidly, due to modernization and urbanization. Little or no work has been done in the area of physicochemical properties of the soils of these forests. In recent times, there has been erosion in the traditional and religious beliefs that had kept these forests protected. The study was thus conducted to compare the soil physicochemical properties of the two sacred forests.

MATERIALS AND METHODS

The Study Area

The study was carried out in two sacred forests located in Farai and Ga'anda Adamawa State, Nigeria. Farai sacred forest lies on latitude 9° 27' 44.26"N of the equator and longitude 12° 05' 21.87"E of the Greenwich meridian (Figure 1). While Ga'anda sacred forest lies on latitude 10° 159399′ N of the equator and longitude 12° 440064′ E of the Greenwich meridian. Both sacred forests are located in the Northern Guinea Savannah Zone of the State. The annual rainfall here is between 900 and 1100m and the rainy season last for about 4-5 months. The Local Government Areas in the zone include Lamurde, Numan, Guyuk Shelleng, Girei, Song, Gombi, Maiha, Hong and northern part of Fufore. The abundant woody plant species in this zone are: *Afzelia africana, Vitellaria paradoxa, Terminalia laxiflora, Terminalia glaucescens, Annona senegalensis, Burkea africana, Prosopis africana, Albizia zygia, Ficus exasperata, Pterocarpus lucens, Detarium microcarpum, Anogeissus leiocarpus, Balanites aegyptica, Tamarindus indica, Sclerocarya birrea, Khaya senegalensis, Ficus syncomorous, Borassus aethiopum, Boswellia dalzielii* and *Ziziphus spina-christi*. The most abundant grass species in this zone include *Pennisetum,* And*ropogon, Hyparrhenia, Bracharia* and *Aristida* (Akosim *et al.,* 2020).

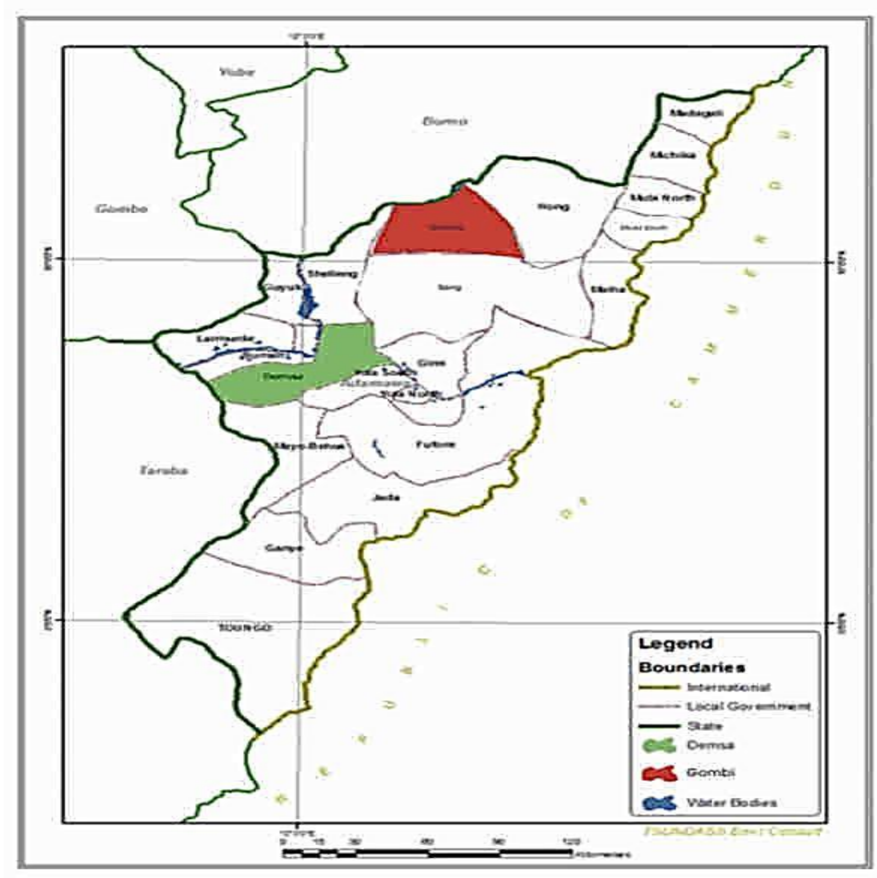

Figure 1: Map of Adamawa State showing the Study Sites

Source: Adebayo *et al.*, (2020)

Data Collection Methods

Collection of soil samples

In each of the sacred forests, a plot of one-hectare 100 m × 100 m was marked out. In each of the selected plots soil samples were randomly collected at ten points from two depths (0–30 cm and 30-60 cm) using auger. The soil samples were put into plastic bags for onward determination of nutrient elements in the Soil Science Laboratory of Modibbo Adama University, Yola, where they were then sieved to pass through a < 2mm sieve. These samples were analyzed for the following physical and chemical properties: Porosity, Bulk Density and Water Holding Capacity, pH, Organic Carbon (OC), Available Nitrogen, Available Phosphorus and Electrical Conductivity (EC), Exchangeable bases (K, Ca, Na, and Mg, Total exchangeable Bases (TEB), Total exchangeable Acidity (TEA) and Effective Cation Exchange capacity (ECEC).

Determination of soil physical properties

Particle size analysis

The particle size analysis was done using the Bouyoucos hydrometer method described by Gee and Bauder (1986).

Bulk densities of the soils

Core samples of soils were used to determine the bulk density in the laboratory using the procedure described by Blake and Hartge (1986) by oven drying the soil sample to a constant weight at 105ºC and dividing the dry weight of the soil by the total volume of the sphere.

$$\mathrm{BD}\ (\mathrm{g}/cm^3) = \frac{\mathrm{WODS\ (g)}}{\mathrm{VS\ (cm^3)}} \ldots\ldots (1)$$

Where:
BD - Bulk density
WODS - Weight of oven dry soil
VS - Volume of soil

Particle density
This was determined after the removal of entrapped air in soils using the pycnometer method as described by Blake and Hartge (1986).

Total porosity
Total porosity of the soil sample was calculated mathematically from the results of bulk density and particle density (Dishan, 2016) using the formula:

$$\mathrm{Tp} = 100 - \left(\left(\frac{\rho b}{\rho p}\right) \times 100\right) \ldots. (1)$$

Where:
Tp - Total porosity
Pb - Bulk density
Pd - Particle density

***Water holding capacity* (WHC)**
The soil water holding capacity analysis was carried out using core sample method. The results obtained was substituted by this expression

$$\mathrm{W.H.C} = \frac{W3-W2}{W4-W1} \times 100 \ldots. (2)$$

Where:
W_1 = covered the bottom of the milk can with the filter paper and weigh on the balance.
W_2 = gentle field a dry soil into the milk can and weigh again.
W_3 = place the filled can on a petri dish and add water to the side of the milk can until water depth is 6mm and leave it to stand overnight and carefully remove the can and weigh again
W4 = Place the can in an oven at a temperature of 105°C for 24 hours and remove to cool down and weigh again

Chemical properties
Soil reaction (pH)
Soil pH was determined by water solutions at a 1:2 soil/water or solution ratio (Agbenin, 1995). Twenty (20) mls of distilled water was added into ten (10) grams of soil samples and stirred. The pH of the suspension was read with a pH meter after 30 minutes.

Electrical conductivity (EC)
Electrical conductivity of the soil saturation extract was determined at a 1:2 soil/water ratio (Udo *et al.*,, 2009).

Organic carbon
Organic carbon contents of the soil samples were determined using dichromate wet oxidation method of Walkley-Black as described by Black (1965) and adopted by (Dishan, 2016).

***Organic matter* (%)**
Value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 (Walkley and Black, 1947; Dishan, 2016).

Total nitrogen (TN)
Total nitrogen was determined by micro Kjeldahl technique (Bremmer and Mulvaney, 1982).

Available phosphorus (AVP)
Available phosphorus in soil was determined following the procedure described by IITA (2002) using Bray-1 extraction method (Bray and Kurtz, 1945).

Exchangeable cations
Exchangeable cations (Ca, Mg, K and Na) in the soil were determined using NH_4OAc saturation method at pH 7.0 as described by Thomas (1982).

Total exchangeable acidity (TEA)
The soil samples were leached with 1M KCl solution. Total exchangeable acidity (H+Al) was determined by titration of the extract with standard NaOH solution (Thomas, 1982) as adopted by (Dishan, 2016). The difference between total exchangeable acidity and exchangeable aluminum give the amount of exchangeable hydrogen.

Effective cation exchange capacity (ECEC)
The effective cation exchange capacity of soil was determined by summing up the exchangeable cations (Ca, Mg, K and Na) and the exchangeable acidity (H+Al) (IITA, 2002).

Base saturation (BS) percentage
The base saturation percentage of soil was calculated for both CEC (NH_4OAc) and ECEC from the formula as adopted by Dishan, (2016)

$$\%BS = [(TEB/CEC\ or\ ECEC)\ x\ 100] \ldots (3)$$

Where:
%BS – Percentage Base saturation
TEB - Total exchangeable bases
CEC - Cation exchange capacity
ECEC - Effective cation exchange capacity

Comparison of factors

i. Student t-test was used to compare the physicochemical parameters of the two studied sites. The formula for the student's t-test is as follows*;*

$$t = \frac{D}{S.P}, \; S.P = \frac{\sum D^2 - \frac{(\sum D)^2}{n}}{n-1} \quad \ldots(4)$$ (Kabir, 2020)

Where:
t = Critical Point
D = Difference between the two sets of data
S.P = Variation of the sum of difference
n = Number of observations
ΣD = Summation of the differences
ΣD^2 = Summation of the square of the differences between the two sets of data which was in computing the calculated t value (critical point) (Kabir, 2020)

RESULTS

Soil Physico-chemical Properties in the Study Sites

Soil physical properties of the study sites

The results of texture classes of soils in Farai sacred forest indicated a variation in textural forms from sandy clay loam, sandy clay, sandy loam and Loamy sand (Table 1). The percentage range of sand, silt and clay of the sampled plot were found to be between 48.80% to 83.20%, 7.6% to 27.6% and 9.20% to 39.20% respectively. Bulk Density of soil in 31-60cm soil depth had the highest value of 1.6g/cm^3, while the lowest was 1.33g/cm^3 in 0-30cm soil depth. The total percentage porosity obtained ranged from 41% to 50% in all the samples. Water holding capacity was between 11.8% and 16%.

The results of the texture classes of soils in Ga'anda sacred forest also indicated a variation in textural forms from sandy loam, sandy clay and sandy clay loam (Table 2). The percentage range of sand, silt and clay of all the samples were between 49.40% to 75.20%, 5.60% to 21.6% and 9.20% to 39.20% respectively. The Bulk Density of soil in 0-30cm region had both the highest and lowest values of 1.58g/cm^3 and 1.34g/cm^3. The total percentage porosity ranged from 40% to 50%. Water holding capacity was between 11.8% and 15%.

Soil physical properties measured in the two sacred forests were compared using student t-test. The result revealed that there were no significant differences ($P \geq 0.05$) in soil physical properties between the two sacred forests (Table 3).

Table 1: Soil Physical properties of Farai Sacred Forest

S/No.	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural classes	B.D (g/cm3)	Porosity (%)	WHC (%)
1	0-30	52.40	19.60	28.00	Sandy clay loam	1.38	48	13.2
2	0-30	52.40	19.60	28.00	Sandy clay loam	1.38	48	13.2
3	0-30	51.20	9.60	39.20	Sandy clay	1.33	50	12.5
4	0-30	48.80	15.60	35.60	Sandy clay	1.34	49	16
5	0-30	62.40	17.60	20.00	Sandy loam	1.45	45	12.5
6	0-30	66.40	13.60	20.00	Sandy loam	1.46	45	15
7	0-30	58.80	27.60	13.60	Sandy clay	1.5	43	15
8	0-30	52.40	19.60	28.00	Sandy loam	1.47	48	13.2
1	30-60	59.20	19.60	21.20	Sandy clay loam	1.44	46	12.4
2	30-60	62.40	19.60	18.00	Sandy loam	1.47	45	13.1
3	30-60	83.20	7.60	9.20	Loamy sand	1.6	39	12
4	30-60	59.20	21.60	19.20	Sandy loam	1.45	45	12.1
5	30-60	62.40	27.60	10.00	Sandy loam	1.55	41	13.2
6	30-60	77.20	9.20	13.60	Sandy loam	1.54	42	13.5
7	30-60	80.20	4.80	15.00	Sandy loam	1.53	42	11.8
8	30-60	77.20	12.60	17.20	Sandy loam	1.49	43	12.12

Key: WHC - Water Holding Capacity; B.D - ***Bulk Density***

Table 2: Soil Physical properties of Ga'anda Sacred Forest

S/No.	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural classes	B.D (g/cm^3)	Porosity (%)	WHC (%)
1	0-30	52.40	19.60	28.00	Sandy clay loam	1.38	48	13.2
2	0-30	52.40	19.60	28.00	Sandy clay loam	1.38	48	13.2
3	0-30	51.20	9.60	39.20	Sandy clay	1.33	50	12.5
4	0-30	48.80	15.60	35.60	Sandy clay	1.34	49	16
5	0-30	62.40	17.60	20.00	Sandy loam	1.45	45	12.5
6	0-30	66.40	13.60	20.00	Sandy loam	1.46	45	15
7	0-30	58.80	27.60	13.60	Sandy clay	1.5	43	15
8	0-30	52.40	19.60	28.00	Sandy loam	1.47	48	13.2
1	30-60	59.20	19.60	21.20	Sandy clay loam	1.44	46	12.4
2	30-60	62.40	19.60	18.00	Sandy loam	1.47	45	13.1
3	30-60	83.20	7.60	9.20	Loamy sand	1.6	39	12
4	30-60	59.20	21.60	19.20	Sandy loam	1.45	45	12.1
5	30-60	62.40	27.60	10.00	Sandy loam	1.55	41	13.2
6	30-60	77.20	9.20	13.60	Sandy loam	1.54	42	13.5
7	30-60	80.20	4.80	15.00	Sandy loam	1.53	42	11.8
8	30-60	77.20	12.60	17.20	Sandy loam	1.49	43	12.12

Key: WHC - Water Holding Capacity; B.D- Bulk Density

Table 3: Student t-test for Soil Physical Properties of the Farai and Ga'anda Sacred Forests

Parameter	t	Df	Sig. (2-tailed)
Sand	0.464	15	0.649 ^{ns}
Silt	0.12	15	0.906 ^{ns}
Clay	-0.454	15	0.656 ^{ns}
Bulk density	0.501	15	0.624 ^{ns}
Porosity	-0.48	15	0.638 ^{ns}
Water Holding Capacity	1.21	15	0.245 ^{ns}

Key:* * *Significant and* ^{ns} *Not significant

Soil chemical properties in the study sites

Table 4 shows the mean values of soil chemical properties of Farai Sacred Forest. The results indicate that the pH values ranged from 5.80 to 7.90. Electrical conductivity values were between 0.02 μs/cm to 13μs/cm. Organic carbon content values ranged from 1.19% to 1.76%. Total Nitrogen content values ranged from 0.12% to 0.30% while Available phosphorous ranged from 6.35mg/kg to 13.76 mg/kg. The exchangeable bases, Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} had their range from 3.20 cmol/kg to 6.40 cmol/kg, 1.10 cmol/kg to 3.60 cmol/kg, 0.17 cmol/kg to 1.70cmol/kg and 0.31 cmol/kg to 0.56 cmol/kg respectively. The mean values of TEB and TEA ranged from 5.65 cmol/kg to 10.12 Cmol/Kg, and 3.20 cmol/kg respectively. The mean values of ECEC ranged from 8.85 cmol/kg to 13.32 Cmol/Kg. Percentage Base Saturation had values between 63.83% and 72.83%.

Table 5 shows the mean values of soil chemical properties of Ga'anda sacred forest. The results indicate that the pH values ranged from 5.80 to 7.60, Electrical conductivity values were between 0.01 μs/cm and 0.29 μs/cm. Organic carbon content value ranged from 0.23% to 1.17% respectively. Total nitrogen content values ranged from 0.02% to 0.20% while Available phosphorous ranged from 5.63 mg/kg to 12.57 mg/kg. The exchangeable bases, Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} had their ranged from 3.20 cmol/kg to 6.40 cmol/kg, 1.20 cmol/kg to 3.60 cmol/kg, 0.22 cmol/kg to 1.00cmol/kg and 0.21 cmol/kg to 0.79 cmol/kg respectively. The mean values of TEB and TEA ranged from 5.50 to 10.43 Cmol/Kg, and 1.20 Cmol/Kg to 3.20 Cmol/Kg respectively. The mean values of ECEC were between 7.07 Cmol/Kg and 12.54 Cmol/Kg. Percentage Base Saturation values was within the range of 63.22% to 89.68%. Student t-test for the soil chemical parameters tested for Farai and Ga'anda sacred forest at ($P \geq 0.05$) level of significance showed that there were significant differences in Org. C, TN, TEA and PBS while the others were not (Table 6).

Table 4: Soil Chemical Properties of Farai Sacred Forest

S/No.	Depth (cm)	PH	EC	OC	TN	AV-P	Ca	Mg	Na	K	TEB	TEA	ECEC	PBS
		1:2	(dS/m)	(%)	(%)	(mg/kg)	(cmol/kg)							(%)
1	0-30	7.70	0.08	1.76	0.18	7.31	5.60	1.32	0.52	0.56	8.01	3.20	11.21	71.44
2	0-30	7.40	0.10	1.49	0.12	7.79	4.20	1.28	0.61	0.49	6.58	3.20	9.78	67.27
3	0-30	7.30	0.05	1.47	0.19	6.59	3.40	2.00	0.70	0.41	6.51	3.20	9.71	67.03
4	0-30	6.90	0.07	1.42	0.06	8.50	5.80	3.60	0.39	0.33	10.12	3.20	13.32	75.98
5	0-30	7.30	0.22	1.41	0.17	13.76	5.20	1.44	0.30	0.49	7.43	3.20	10.63	69.90
6	0-30	7.50	0.12	1.38	0.26	8.26	6.40	1.20	0.30	0.49	8.39	3.20	11.59	72.39
7	0-30	6.60	0.08	1.36	0.26	11.37	3.20	1.20	0.91	0.33	5.65	3.20	8.85	63.83
8	0-30	7.20	0.19	1.30	0.30	10.89	5.60	1.24	0.30	0.31	7.45	3.20	10.65	69.96
1	30-60	6.50	0.13	1.29	0.18	6.83	3.80	1.28	0.57	0.49	6.13	3.20	9.33	65.71
2	30-60	6.20	0.16	1.29	0.20	12.57	5.40	1.10	0.43	0.31	7.24	3.20	10.44	69.34
3	30-60	6.30	0.03	1.28	0.17	7.07	4.40	2.00	0.17	0.42	6.99	3.20	10.19	68.60
4	30-60	7.90	0.16	1.26	0.18	10.65	5.60	1.60	0.57	0.26	8.02	3.20	11.22	71.48
5	30-60	7.19	0.42	1.25	0.20	6.59	5.40	1.68	0.61	0.51	8.20	3.20	11.40	71.93
6	30-60	7.60	0.16	1.22	0.16	6.35	5.60	1.88	0.52	0.56	8.57	3.20	11.77	72.80
7	30-60	5.80	0.02	1.21	0.13	9.22	5.40	2.00	0.32	0.44	8.16	3.20	11.36	71.82
8	30-60	6.10	0.21	1.19	0.15	7.31	5.60	2.40	0.22	0.36	8.58	3.20	11.78	72.83

Key: EC - Electrical conductivity; OC - Organic Cabon; TN - Total Nitrogen;TEB -Total Exchangeable Base; TEA -Total Exchangeable Acid; ECEC -Effective cation exchange capacity; PBS - Percentage Base Saturation

Table 5: Soil Chemical Properties of Ga'anda Sacred Forest

S/No.	Depth (cm)	pH	EC	OC	TN	AV-P	Ca	Mg	Na	K	TEB	TEA	ECEC	PBS
		1:2	(dS/m)	(%)	(%)	(mg/kg)	(cmol/kg)							(%)
1	0-30	7.30	0.14	1.17	0.17	10.18	4.80	1.32	0.70	0.21	7.02	3.20	10.22	68.69
2	0-30	7.40	0.19	1.16	0.15	11.37	4.40	2.60	0.26	0.69	7.95	3.20	11.15	71.31
3	0-30	7.40	0.09	1.15	0.20	12.57	5.40	1.86	0.30	0.49	8.05	3.20	11.25	71.56
4	0-30	7.40	0.18	1.13	0.10	8.50	6.40	1.64	0.61	0.69	9.34	3.20	12.54	74.48
5	0-30	7.30	0.17	1.12	0.15	7.55	3.20	1.20	0.30	0.79	5.50	3.20	8.70	63.22
6	0-30	7.80	0.29	1.07	0.17	6.83	4.80	1.92	0.65	0.44	7.81	3.20	11.01	70.93
7	0-30	7.30	0.07	1.05	0.18	6.83	4.80	1.68	0.39	0.54	7.41	3.20	10.61	69.84
8	0-30	6.60	0.12	1.05	0.12	8.98	4.80	1.32	0.65	0.31	7.08	3.20	10.28	68.87
1	30-60	5.80	0.13	1.04	0.16	5.63	3.60	2.80	1.00	0.31	7.71	3.20	10.91	70.66
2	30-60	7.50	0.15	1.04	0.06	12.09	6.40	1.30	0.61	0.54	8.85	3.20	12.05	73.44
3	30-60	7.60	0.19	1.02	0.19	7.07	4.40	1.76	0.43	0.44	7.03	3.20	10.23	68.72
4	30-60	6.70	0.22	0.91	0.10	11.13	4.60	1.88	0.22	0.49	7.18	3.20	10.38	69.19
5	30-60	6.60	0.04	0.86	0.09	7.79	4.80	1.60	0.65	0.77	7.82	1.20	9.02	86.70
6	30-60	7.50	0.01	0.83	0.08	10.89	4.80	1.40	0.35	0.67	7.21	2.40	9.61	75.04
7	30-60	6.70	0.04	0.70	0.07	8.98	3.20	2.00	0.39	0.28	5.87	1.20	7.07	83.03
8	30-60	6.30	0.03	0.23	0.02	7.79	5.60	3.60	0.57	0.67	10.43	1.20	11.63	89.68

Key: EC - Electrical conductivity; OC - Organic carbon TN - Total nitrogen; TEB - Total Exchangeable base; TEA - Total Exchangeable acid; ECEC - Effective cation exchange capacity; PBS - Percentage Base Saturation

Table 6: Student t-test for Soil Chemical Properties of the Farai and Ga'anda Sacred Forests

Chemical Properties	t	Df	Sig. (2-tailed)
pH	-0.597	15	0.56^{ns}
EC	1.011	15	0.328 ^{ns}
OC	8.321	15	0.000*
TN	3.413	15	0.004*
AvP	-0.251	15	0.806 ^{ns}
Ca	0.964	15	0.35^{ns}
Mg	-0.809	15	0.431^{ns}
Na	-0.52	15	0.61^{ns}
K	-1.929	15	0.073^{ns}
TEB	-0.041	15	0.968^{ns}
TEA	2.109	15	0.052*
ECEC	0.948	15	0.358^{ns}
PBS	-2.04	15	0.059*

***Key: * ****Significant and ^{ns} Not significant; EC - Electrical conductivity; OC - Organic carbon; TN - Total Nitrogen; TEB - Totalex changble base; TEA - Total Exchangeable acid; ECEC - effective cation exchange capacity; PBS - Percentage Base Saturation; AvP - Available phosphorus*

DISCUSSION

Soil Physico-chemical Properties in the Study Sites

Soil physical properties in the sacred forests

The textural classes in both sacred forests fall in the loam sand class. The results of the soil physical properties agree with McCauley *et al.*, (2005) in his study of Soil and Water Management. Similar trends in particle size distribution have been reported by Oyelowo *et al.*, (2021) in their study of physiochemical characteristics of soils in two sacred forests of Southwestern, Nigeria.

The Bulk Density of the two sacred forests are within the range of 1.33 to 1.6. These figures are slightly higher than those reported by Falade and Taiwo (2019) in their study of forest structure and carbon stocks of Osun-Osogbo sacred grove Nigeria, where they obtained a range between 1.40 and 1.71 in the old growth and 1.41 and 1.70 in the Regrowth. The variation in B.D might be due to soil structure, texture and organic matter.

The Water Holding Capacity of the two sacred forests ranged from 11.8 to 16 and do not vary significantly. The ranges of WHC in the sacred groves are very low when compared with the findings of Sathe *et al.*, (2018) in their study of nutrients status of soil samples of few sacred groves from arid region of Sangli district, Maharashtra, India where they obtained a range between 38 and 49. The low values WHC in the study sites may be attributed to high sand particles and gravels which are known to be responsible for low WHC in soils.

Chemical properties of soils in the sacred forests

From this study pH ranged from 5.80 to 7.90 indicating that the soils were moderately acidic to slightly alkaline with significant differences ($p \leq 0.05$) observed among the samples in Farai sacred grove soil subsurface layer. The high pH values recorded in the sacred forests is in conformity with the study of Oyelowo *et al.*, (2021) in their study of physiochemical characteristics of soils in two sacred forests of Southwestern, Nigeria where they obtained a range between 7.30 and 7.39 in the surface soil and 7.38 to 7.55 in the subsurface layer of the sacred forests. They attributed their findings to the presence of moderate exchangeable Ca and Mg in the soil.

The organic carbon of the two studied sacred forests soils ranged from 1.19 % to 1.76 % and 0.23% to 1.17 % respectively and also vary significantly. The significant variation of organic carbon content recorded in the soils could be ascribed to the decomposition of plant liter and dead soil macrofauna and micro-organisms in the forests floor. These parameters are within tolerable level to support tree growth. The total nitrogen content in the soils ranged from 0.06 to 0.30 % and 0.02 % to 0.20 % and were statistically different ($p \geq 0.05$) in the two sacred forests. The TN value was generally low (2.1-2.4 gkg^{1}) using FFD, 2002 standard in the two sacred forests. These values are lower than the values obtained by Opeyemi *et al.*, (2020) in their study of Physical and Chemical Properties of Soils in Gambari Forest Reserve where they obtained a range from 0.35 to 0.66 gkg^{1}. The variation may be attributed to fragmentation of forests which can reduce soil organic carbon and pH.

The values of exchangeable cations in the studied sacred forest soils were Farai; Ca^{2+}, Mg^{2+}, Na^+ and K^+ with the corresponding range from 3.20 cmol/kg to 6.40 cmol/kg, 1.10 cmol/kg to 3.60 cmol/kg, 0.17 cmol/kg to 1.70cmol/kg and 0.31 cmol/kg to 0.56 cmol/kg and Ga'anda Ca^{2+}, Mg^{2+}, Na^+ and K^+ had their ranged from 3.20 cmol/kg to 6.40 cmol/kg, 1.20 cmol/kg to 3.60 cmol/kg, 0.22 cmol/kg to 1.00cmol/kg and 0.21 cmol/kg to 0.79 cmol/kg respectively. These range of exchangeable bases are not significantly different between the two sacred forests. The comparatively low values of exchangeable cations may be attributed to soil nutrient losses through human activities or climatic factors which leads to leaching that can prompt mobilization and immobilization of these cations (Suleiman *et al.*, 2017). This study is consistent with the findings of Oyelowo *et al.,* (2019) in their study of physiochemical characteristics of soils in two sacred forests of Southwestern, Nigeria were they recorded values for Na ranged from 0.29 to 0.36 c mol. Kg^{-1}, K (0.32 to 1.29 c mol. kg^{-1}), Ca (11.82 to 15.06 c mol. kg^{-1}) and Mg (1.22 to 3.40 c mol. kg^{-1}) at 0 – 15 cm depth. While at 15-30 cm, the values for Na ranged from 0.28 to 0.35 c mol. kg^{-1}, K (0.33 to 1.28c mol kg^{-1}), Ca (11.64 to 21.42 c mol.kg^{-1}), and Mg (2.44 to 2. 84 c mol. kg^{-1}) at Igbo Ile and Igbo Oba respectively.

The ECEC values were also similar among the two forests and not significantly different ($p \leq 0.05$). Cation exchange capacity (ECEC) is an overall assessment of the fertility of a soil, and the values depend on pH (Brady and Weil, 1999). The ECEC values obtained in this study are not within the same range with those reported by Tufa *et al.,* (2019) in their study of Effects of land use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia where they reported mean values under grass, cultivated, forest and grazing lands at 38.5, 33.2, 41.7 and, 30.1 cmolc kg^{-1} respectively.

Percentage Base Saturation values of Farai and Ga'anda sacred forest were from 63.83% to 72.83% and 63.22% to 89.68% and were statistically different ($p \geq 0.05$). This study is in agreement with the studies of Tufa *et al.,* (2019) in their study of Effects of land use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia, were they had value ranges from 74.0% to 82.9% which is said to be very high range for forest soils (Hazelton and Murphy, 2007).

CONCLUSION

From the findings of this study, it can be concluded that the soil texture of the two sacred forest are the same, i.e. sandy loam. It is well drained which implies that nutrient elements and water will readily be available for the plant uptake. The observed soil nutrient levels in the sacred forest soils showed that while some nutrient concentrations are significantly different some are not leading to the conclusion that some nutrients are depleted others are enhanced through decomposition from organic matter, while some are unaffected. Nutrient analysis of the soils showed that some sites have high levels of nutrients necessary for tree species flourishing while others do not. The values of parameters recorded in the study areas showed that the sacred forests are less disturbed which therefore means that forest soils are richer in nutrients.

Recommendation

It is thus recommended that conservation of sacred forests particularly in the semi-arid regions of Nigeria should be encouraged.

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