IJAAR PUBLISHING®

Scholarly Journal of Science and Technology Research & Development | ISSN: **2955-0807**
Vol. 2, Issue 6 (June, 2023) | www.ijaar.org/sjstrd

Comparative Assessment of Physico-Chemical Properties of Soil in Different Ecological Zones of Western Niger Delta, Nigeria

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Abstract

The study examined the comparative assessment of physico-chemical properties of soil in different ecological belts of Western Niger Delta, Nigeria. Eight 20m x 20m quadrat were delimited in the natural vegetation in each of the rainforest (RF), mangrove (M), fresh water swamp (FWS) and guinea savanna (GS) ecological belts to collect soil samples. Soil samples were collected from the topsoil (0-15cm) and subsoil (15-30cm) and were taken to laboratory for further analysis. Descriptive statistics and inferential statistics were used for data analysis. Findings showed that in the topsoil, the silt content was highest in FWS (17.37±4.8%). The bulk density, total porosity and water holding capacity were slightly varied among the four ecological zones. In the subsoil, the mean soil moisture was significantly highest in the M (31.13±3.2%) and the silt content was highest in the RF. The soil moisture, sand, silt and clay were significantly varied among the ecological zones in both topsoil and subsoil. Findings revealed that soil pH was acidic in all the ecological zones. The organic C, total N, available P, exchangeable Mg and exchangeable acidity were considerably highest in the FS in both topsoil and subsoil. Significant variation was found in the soil moisture, sand, silt, clay, pH, organic C, total N, available P, Ca, Mg, K, CEC, Pb, Mn, Fe, Cu, and Zn among the ecological zones in both topsoil and subsoil. The study concluded that bulk density, total porosity and water holding capacity were slightly varied among the four ecological zones but soil moisture was highest in M. The organic C, total N, available P, exchangeable Mg and exchangeable acidity were considerably highest in the FWS while concentrations of Pb, Cu, Zn and Fe were highest in the topsoil of RF. It is recommended among others that the physical soil properties especially sand, silt, and total porosity in the topsoil should be maintained in the ecological zones to support the livelihood of soil biodiversity.

Keywords: Physical, Chemical, Ecological belts, Descriptive, Inferential, Topsoil, Subsoil

Published *02/06/2023*

Olisa C. O., Akinloye K.F., Idisi E.B. and Eludoyin O.S. (2023). Comparative Assessment of Physico-Chemical Properties of Soil in Different Ecological Zones of Western Niger Delta, Nigeria. *Scholarly Journal of Science and Technology Research & Development*, 2(6), 1-19.

Introduction

Soil-plant interrelations are dynamic and must be regarded as interacting components in any ecosystem (Brian *et al*, 1999). Vegetation and soil are the two main components of terrestrial ecosystems and the succession of vegetation is often accompanied by changes in soil properties (Carter et al., 1994). With reference to the interactive soil-vegetation feedback, soil provides essential nutrients for vegetation growth and development, and this in turn may drive some of the changes in soil formation and modification (Kardo et al. 2006). Soil properties are considered one of the major factors that affect the distribution patterns of forest types (Toriyama et al., 2007). Soil properties from each preceding community, which increase in organic matter and profile development, and different ecological zones together with modification of the light environment, are the two main explanations for succession (Goudie, 1989). The impacts of vegetation on soil can also be illustrated by land degradation, which is a regressive succession. Several studies showed that land degradation is accompanied with biotic changes of diversity loss, chemical changes of decreasing soil nutrients, and physical changes with respect to infiltration, percolation, aeration, and, ultimately erodability (Carter et al., 1994).Plant growth is dependent on availability of water and nutrients in the rhizosphere, the soil-root interface consisting of a soil layer varying in thickness between 0.1mm and up to a few millimeters depending on the length of the root lairs in different ecological zones. Very importantly also, availability of nutrients in the rhizosphere is controlled by the combined effects of soil properties and interactions between plant adjacent soil organism in the surrounding soil (Brian *et al*., 1999). Generally, the environmental factors that influence plant growth also impact the activity of soil organisms and the rate of organic matter decomposition. These factors such as aeration, moisture, temperature and nutrient availability in soil can vary due to different activities in the ecological zones of a particular place. Plants in natural and agricultural systems are not only exposed to above-ground environments but are also at the mercy of fluctuations in belowground conditions. While soil is one of the Earth’s most precious resources underpinning the success of natural and agricultural systems, it is also one of the least understood due its considerable heterogeneity and complexity. The plant-soil system includes physical, chemical, and (micro and macro) biological components which interact and modify the composition and structure of localised-environments, in turn impacting on how they function such as soil’s ability for flood mitigation, carbon sequestration, and nutrient cycling. Climate change adds further pressure on these processes increasing the need for sustainable management practices (Mooney, 2023). There are several studies on the soil properties but few have shown concern about the variation in the physical and chemical properties of soil in different ecological zones especially in the tropical environment like Nigeria. It is therefore noted that the present study examined the comparative assessment of physico-chemical properties of soil in different ecological zones of Western Niger Delta, Nigeria.

Material and Methods

The study area is the Western Niger Delta Region of Nigeria. It is located between longitude 4^o 15’ 0”E and 7^o 0’ 0”E and latitude 5^o 0’ 0”N and 7^o 30’ 0”N. The Western Niger Delta Region comprises Ondo, Edo and Delta States (Figure 1). The study area involved the four ecological zones namely guinea savanna, rainforest, fresh water swamp and mangrove in the Western Niger Delta Region. The study area is located in the tropics and therefore experiences humid tropical climate (Adejuwon, 2012). It has distinct dry and wet seasons. Between 8 and 10 months in the year, the climate of the region is dominated by tropical maritime (mT) air mass while the remaining 2 to 4 months of the year are under the influence of the dry tropical continental (cT) air mass (Adejuwon, 2012). The annual temperature range is small as low as 3^0C. Mean monthly temperature is 26-28^0C (Adejuwon, 2012). Rainfall is between 1800mm and 3000mm per year (Ologunorisa and Adejuwon, 2003; Emaziye, et al., 2012). Relative humidity is about 85% and the relief of study area comprises of coastal plain. It is generally low lying without remarkable hills, consisting of unconsolidated sediments of quaternary age. Some hills can be found northwards within the Aniocha LGA in Delta State and northern parts of Ondo State. Thus, the relief of the region includes coastal lowland, the Esan Plateau, Orle valley, the dissected uplands of Akoko-Edo and Akure-Owo axis (Adejuwon, 2012). The soil types are made up of ferrosols predominantly dominated by sandy and little clay composition (Imoroa, 2000; Okoh, 2013). Geologically, the study area is underlain by the Coastal Plain sands having its place from the Pleistocenic Formation (Nwakoala and Warmate, 2014). The drainage of the study area is made up of River Niger that discharges into the sea through its several distributaries such as the Forcados, Escravos and Warri rivers and creeks such as the Bomadi Creeks, amongst others (Aweto, 2001; Okoh, 2013). Rivers Jamieson and Ethiope rise from the north and northeast respectively and subsequently join and form the Benin River, which eventually discharges into the sea in the West (Emaziye et al., 2012). Also importantly, River Osse in Ondo State which also discharges into the Atlantic Ocean. The study area comprises natural vegetation of lowland rainforest with patches of swamp vegetation. The forest was a major source of timber and the notable timber producing species include *Antiaris toxicaria*, *Milicia excelsa*, *Ceiba pentandra*, *Piptadeniastrum africanum*, *Pentaclethra macrophylla*, *Chrysophyllum albidum* and *Irvingia gabonenesis* (Okoh, 2013).

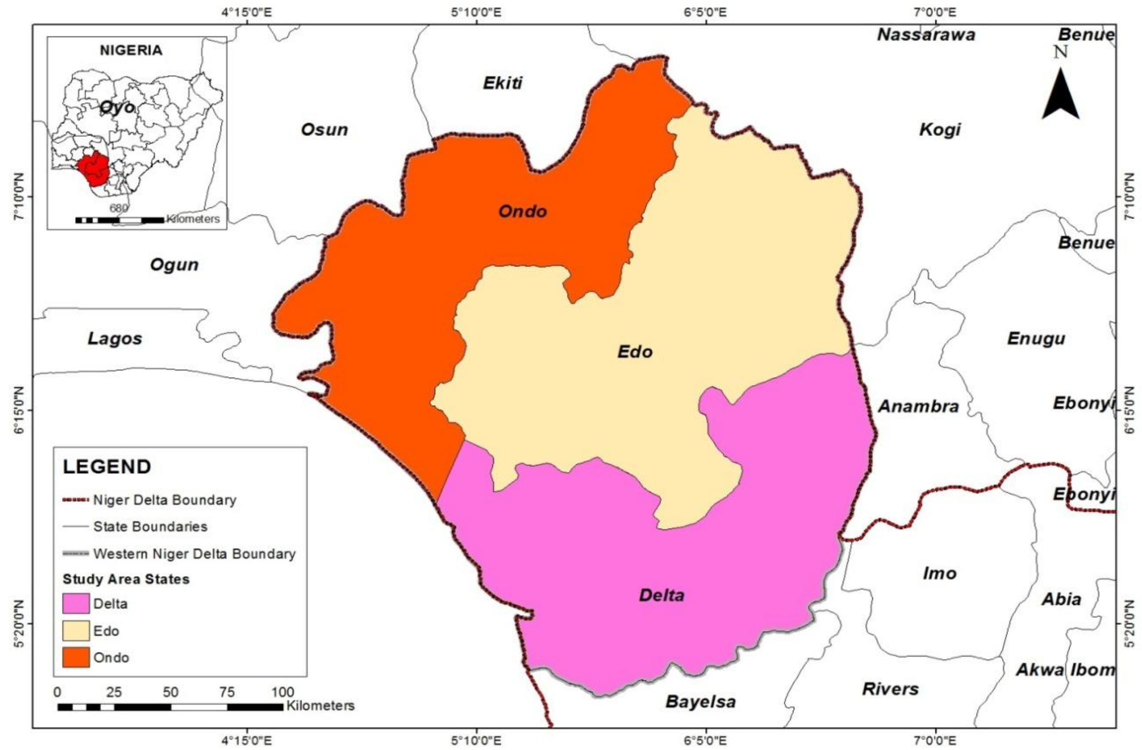

Figure 1: Western Niger Delta

A quadrat of 80m x 100m was delimited in natural (virgin) vegetation in the four ecological zones of the Western Niger Delta (Shen, 2011). This quadrat was sub-divided into quadrats of 20m x 20m from which eight (8) quadrats were randomly selected for data collection on soil samples in each ecological belt. Five soil samples were collected from each 20m x 20m quadrat using soil auger at the depth of 0-15cm (topsoil) and 15-30cm (subsoil). The soil samples in each depth were bulked together into a plastic container and a composite soil sample was taken in each quadrat from topsoil and subsoil. Thus, 8 soil samples were collected from each 20m x 20m quadrat the depth of 0-15cm (topsoil) and 15-30cm (subsoil) in the ecological zone. Composite soil samples were collected into well-labelled polythene bags and brought into the laboratory. The soil samples were air-dried and carefully sieved with 2mm diameter mesh in order to separate the soil from stones. Thereafter, the soil samples were taken to the laboratory for analysis to determine the levels of the physical and chemical properties of soils in the ecological belts. Soil particle size composition was analyzed using the hydrometer method of (Bouyoucos, 1926), bulk density and total porosity were determined using core method (Ichikogu, 2012) and water holding capacity as described in Dutta and Agrawwal (2002). Soil temperature were measured with soil thermometer *in situ* (Ochsner, 2008) while soil moisture was measured using gravimetric method (Su et al., 2014). Exchangeable bases which included Calcium (Ca), Potassium (K), and Sodium (Na) were determined using flame photometry, and Magnesium (Mg) using atomic absorption spectrophotometer. Cation Exchange Capacity (CEC) was determined using the summation method (Chapman, 1965) and total Nitrogen (N) was determined using Kjeldahl method. Available Phosphorus (P) was determined using spectophotometric method (Ogbonna and Okeke, 2011). Soil pH was determined using saturated paste extract while organic carbon was determined by Walkey and Black's rapid titration method (Walkey and Black, 1934). Descriptive statistics were used to describe the mean values of soil properties. Inferential statistics which include analysis of variance (ANOVA) was used to determine the significant variations in soil properties across the ecological zones in the study area (Cornish, 2006).

Results and Discussion

Physical Properties of Soil across the Ecological Zones

The physical properties of soil in the topsoil and subsoil are shown in Tables 1. In the topsoil, soil moisture was highest in the mangrove (30.00%) and the lowest was observed in guinea savanna (12.50%). Temperature was slightly varied among the four ecological zones but temperature was higher in guinea savanna with a mean temperature of 27.37 ^{o}C. Among the soil particles size distribution (sand, silt and clay), sand recorded the highest. Sand content was highest in mangrove (87.20%) and the lowest was observed in the freshwater swamp (62.35%). Considering silt content, fresh water swamp recorded 17.37% as the highest among the ecological zones, rainforest recorded 13.90% while mangrove recorded 7.40% and guinea savanna recorded 8.97%. The bulk density slightly varied in the four ecological zones, but guinea savanna recorded the highest with mean value of 1.48 g/cm^3 and the least was observed in mangrove recording 1.44 g/cm^3. The porosity and water holding capacity varied slightly among the ecological zones. However, soil porosity was highest in mangrove. This may be attributed to the high sand content which might have enabled wider pore space within the soil. The water holding capacity was highest in the rainforest with the mean value of 44.81%.

In subsoil, the mean soil moisture was highest in the mangrove (31.13%) while the least was observed in guinea savanna (12.75%). The soil temperature was highest in guinea savanna (27.56 ^{o}C) and lowest was found in the mangrove (26.88 ^{o}C). Similarly, the sand content was predominantly higher in the subsoil among the particle size composition. The highest sand content was found in mangrove (84.70%) and the lowest sand content was recorded fresh water swamp (70.22%). Meanwhile, the silt content was highest in the rainforest (15.40%) and the least was recorded in guinea savanna (6.98%). The clay content was highest in fresh water swamp (20.14%) and the least was recorded in mangrove (6.90%). The bulk density was highest in the freshwater swamp (1.48 g/cm^3) and the lowest was found in mangrove (1.42 g/cm^3). The total porosity was slightly higher in the mangrove (47.00%) than other ecological zones while the water holding capacity was highest in the rainforest (44.68%). The soil moisture and soil temperature were higher in the subsoil than the topsoil across the ecological zones.

Table 1: Soil Physical Properties at the Topsoil and Subsoil

Soil Depth	Soil Properties	Rainforest	Mangrove	Guinea Savanna	Fresh Water Swamp
Topsoil (0-15cm)		Mean±SD	Mean±SD	Mean±SD	Mean±SD
	Soil Moisture (%)	13.75±5.2	30.00±0.1	12.50±3.8	21.25±3.5
	Temperature (^oC)	27.25±0.5	26.75±0.7	27.37±0.5	27.25±0.5
	Sand (%)	78.47±4.9	87.20±4.6	80.60±2.1	62.35±7.0
	Silt (%)	13.90±4.6	7.40±3.7	8.97±1.5	17.37±4.8
	Clay (%)	7.63±2.7	5.40±3.1	10.43±1.0	20.38±3.9
	Bulk Density (g/cm^3)	1.46±0.1	1.44±0.8	1.48±0.1	1.47±0.1
	Total Porosity (%)	45.00±3.7	45.25±3.3	43.38±2.0	44.37±2.6
	Water Holding Capacity (%)	44.81±0.8	44.13±1.4	44.38±1.3	44.07±1.9
Subsoil (0-15cm)	Soil Moisture (%)	15.50±1.3	31.13±3.2	12.75±3.6	25.13±3.4
	Temperature (^oC)	27.38±0.2	26.88±0.6	27.56±0.4	27.44±0.3
	Sand (%)	76.73±7.5	84.70±4.2	84.60±2.6	65.23±9.5
	Silt (%)	15.40±7.3	8.40±4.7	6.98±2.7	14.63±4.5
	Clay (%)	7.87±1.5	6.90±1.9	8.42±1.7	20.14±4.6
	Bulk Density (g/cm^3)	1.46±0.2	1.42±0.1	1.44±0.1	1.48±0.5
	Total Porosity (%)	44.25±1.5	47.00±2.8	46.00±3.3	44.00±2.1
	Water Holding Capacity (%)	44.68±0.8	44.25±1.3	44.25±0.8	43.98±1.3

N=8

Soil Chemical Properties across the Ecological Zones

The analyses of soil chemical properties across the ecological zones at both the topsoil and subsoil are presented in Table 2. In the topsoil, the soil pH was acidic across the ecological zones but more acidic in the freshwater swamp (4.45) and less acidic in mangrove (5.50). The organic C was 5.57% in the freshwater swamp; 3.84% in mangrove, 3.05% in the rainforest and 1.80% in the guinea savanna. Similarly, total N was highest in the freshwater swamp (0.41%) and the least was found in guinea savanna with mean value of 0.16%. Available P in the topsoil was 23.40 mg/kg in the freshwater swamp which was the highest of all the ecological zones, 16.80 mg/kg in the rainforest, 11.55 mg/kg in the mangrove and 8.55 mg/kg in guinea savanna. The exchangeable Ca was highest in the mangrove (3.87 Cmol/kg) while the lowest was observed in both rainforest and fresh water swamp having 1.07 Cmol/kg. Exchangeable Mg ranged from 0.43 Cmol/kg in the freshwater swamp to 1.27 Cmol/kg in the mangrove. Exchangeable K was highest in guinea savanna with a mean value of 0.48 Cmol/kg and the lowest was observed in the rainforest with a mean value of 0.27 Cmol/kg. Furthermore, exchangeable Na was highest in the mangrove (0.31 Cmol/kg) while the lowest was found in guinea savanna (0.24 Cmol/kg). The mean CEC for rainforest in the topsoil was 4.78 Cmol/kg in the rainforest, 6.55 Cmol/kg in mangrove, 3.85 Cmol/kg guinea savanna and 11.03 Cmol/kg in the freshwater swamp. The exchangeable acidity in the topsoil was highest in the freshwater swamp (8.82 Cmol/kg) and lowest in mangrove (0.72 Cmol/kg). Considering the heavy metals in the topsoil, mean Pb was highest in the rainforest (9.09 mg/kg) while mangrove, guinea savanna and freshwater swamp had 7.84 mg/kg, 7.49 mg/kg, and 8.06 mg/kg respectively. It was discovered that mean Mn was high across the ecological zones but this was highest in the freshwater swamp (295.87 mg/kg) and the least was observed in mangrove (251.50 mg/kg). Mean Fe was highest in the rainforest (504 mg/kg) and the lowest was found in the guinea savanna (103.96 mg/kg). Mean Cu had the least concentration in the entire study area compared to all trace elements investigated in this study. Meanwhile the mean Cu was highest in the rainforest (0.83 mg/kg) and lowest in the freshwater swamp (0.15 mg/kg). Mean Zn concentration across the entire study area was similar to Pb and Fe concentrations in the study area whereby the highest concentration of Zn was found in the rainforest with a mean value of 13.07 mg/kg and the lowest was found in guinea savanna with a mean value of 5.97 mg/kg.

In the subsoil, the mean soil pH observed in the entire study area was acidic and it followed similar trend with the topsoil whereby freshwater swamp has the highest level of acidity (4.47) and the least was found in mangrove (5.50). Both organic C and total N were higher in the topsoil than the subsoil and follow the same trend as freshwater had the highest mean organic C (4.57%) and total N (0.42%) while guinea savanna had the lowest organic C(1.41%) and total N (0.12%). Similar to topsoil, the available P was highest in the freshwater swamp with a mean value of 27.01 mg/kg and the lowest was found in guinea savanna (7.38 mg/kg). Available P was higher in the topsoil across the ecological zones except in the mangrove where it was slightly higher in the subsoil. Exchangeable Ca was highest in mangrove (4.18 Cmol/kg) and least was found in guinea savanna (7.38 mg/kg) while mean exchangeable Mg was highest in the mangrove (1.26 Cmol/kg) and lowest in the freshwater swamp (0.41 Cmol/kg). The exchangeable K was 0.51 Cmol/kg, 0.44 Cmol/kg, 0.34 Cmol/kg and 0.26 Cmol/kg in guinea savanna, freshwater swamp, mangrove and rainforest respectively. Mean Na concentration in subsoil was slightly varied from the topsoil and except mangrove, Na concentration was higher in the topsoil than the subsoil. Moreover, the mean CEC was highest in the freshwater swamp (9.27 Cmol/kg) and the least was observed in guinea savanna (3.53 Cmol.kg). The exchange acidity was also highest in freshwater swamp (7.25 Cmol/kg) and least in mangrove (0.97Cmol/kg). The concentration of Pb was highest in the rainforest (9.46 mg/kg) and the lowest concentration was found in the mangrove with a mean value of 7.02 mg/kg. The concentrations of Mn and Fe were highest in the freshwater swamp with mean values of 283.00 mg/kg and 295.00 mg/kg respectively. However, Mn concentration was lowest in rainforest (240.00 mg/kg) while the lowest concentration of Fe was observed in guinea savanna (125.16 mg/kg). The concentrations of Cu and Zn in the subsoil were observed to be highest in mangrove with mean values of 0.57 mg/kg and 9.94 mg/kg respectively.

Table 2: Soil Chemical Properties at the Topsoil and Subsoil across the Ecological Zones

Soil Depth	Soil Properties	Rainforest	Mangrove	Guinea Savanna	Fresh Water Swamp
		Mean±SD	Mean±SD	Mean±SD	Mean±SD
Topsoil (0-15cm)	pH (H_2O)	4.85±0.2	5.51±0.3	4.70±0.2	4.45±0.1
	Organic C (%)	3.05±.4	3.84±1.4	1.80±0.6	5.57±1.6
	Total N (%)	0.24±0.2	0.31±0.1	0.16±0.6	0.41±0.2
	Available P (mg/kg)	16.80±1.9	11.75±2.4	8.55±1.5	23.40±4.1
	Ca (Cmol/kg)	1.07±0.8	3.87±0.5	1.22±0.3	1.07±0.4
	Mg (Cmol/kg)	0.57±0.3	1.27±0.1	0.47±0.1	0.43±0.1
	K (Cmol/kg)	0.27±0.0	0.35±0.2	0.48±0.1	0.47±0.1
	Na (Cmol/kg)	0.28±0.1	0.31±0.6	0.24±0.0	0.27±0.9
	CEC (Cmol/kg)	4.78±2.7	6.55±0.9	3.85±1.0	11.03±3.3
	Ex. Acidity (Cmol/kg)	2.60±1.7	0.72±0.3	1.42±0.9	8.82±3.3
	Pb (mg/kg)	9.09±1.6	7.84±1.0	7.49±0.9	8.06±3.4
	Mn (mg/kg)	239.25±18.1	251.5±28.1	265.25±24.9	295.87±64.0
	Fe (mg/kg)	504.00±194.3	148.31±64.1	103.96±33.5	380.37±95.1
	Cu (mg/kg)	0.83±0.2	0.55±0.1	0.29±0.1	0.15±0.1
	Zn (mg/kg)	13.07±8.3	8.54±1.6	5.97±1.0	5.80±0.8
Subsoil (15-30cm)	pH (H_2O)	4.93±0.1	5.59±0.2	4.73±0.3	4.47±0.0
	Organic C (%)	2.64±2.2	3.46±0.8	1.41±0.5	4.57±2.2
	Total N (%)	0.21±0.2	0.29±0.1	0.12±0.0	0.42±0.2
	Available P (mg/kg)	14.81±1.2	12.18±2.9	7.38±1.7	27.01±1.5
	Ca (Cmol/kg)	1.26±0.6	4.18±0.5	1.20±0.4	0.92±0.3
	Mg (Cmol/kg)	0.61±0.3	1.26±0.2	0.46±0.2	0.41±0.2

	K (Cmol/kg)	0.26±0.0	0.34±0.1	0.51±0.1	0.44±0.1
	Na (Cmol/kg)	0.27±0.0	0.30±0.1	0.25±0.0	0.25±0.1
	CEC (Cmol/kg)	4.96±3.1	7.10±1.1	3.53±0.5	9.27±1.8
	Ex. Acidity (Cmol/kg)	2.52±2.3	0.97±0.5	1.10±0.6	7.25±2.6
	Pb (mg/kg)	9.46±1.7	7.02±1.1	7.41±2.0	7.66±1.2
	Mn (mg/kg)	240.00±10.7	272.25±14.6	279.00±22.4	283.00±44.2
	Fe (mg/kg)	156.45±105.1	167.47±56.8	125.16±38.9	295.00±74.3
	Cu (mg/kg)	0.40±0.4	0.57±0.1	0.29±0.1	0.03±1.5
	Zn (mg/kg)	8.27±3.3	9.94±2.4	5.53±0.8	0.94±3.6

N-8

Variations in the Soil Properties between Topsoil and Subsoil across the Ecological Zones

The variation in soil properties between topsoil and subsoil was determined using pairwise t-test and shown in Table 3. Similarly, variation of soil properties across the ecological zones determined by analysis of variance is shown in Table 3. The pairwise t-test revealed that none of the physical properties of soil varied significantly between topsoil and subsoil at p<0.05. However, generally, physical properties of soil such as temperature, silt, clay, bulk density and water holding capacity in the topsoil were slightly higher than that of subsoil. Whereas soil moisture, sand and total porosity were slightly higher in the subsoil than the topsoil. In the topsoil, analysis of variance revealed that there was a significant variation in soil moisture (F=38.89; p<0.05), sand (F=36.10; p<0.05), silt (F=11.05; p<0.05) and clay (F=14.87; p<0.05) among the ecological zones. Also, in the subsoil, significant variation existed in soil moisture (F=36.87; p<0.05), sand (F=15.33; p<0.05), silt (F=5.71; p<0.05) and clay (30.46; p<0.05). Table 4 shows the variations in the chemical soil properties between the topsoil and subsoil across the ecological zones. It is shown that significant variation existed in soil pH (t=2.760; p<0.05) and organic C (t=2.183; p<0.05) between topsoil and subsoil. In the topsoil, analysis of variance shows that significant variation was observed in pH (F=46.68; p<0.05), organic C (F=7.11; p<0.05), total N (F=4.28; p<0.05), available P (F=4.35; p<0.05), Ca (F=53.07; p<0.05), Mg (34.34; p<0.05), K (5.18; p<0.05), CEC (15.76; p<0.05), Mn (F=3.26; p<0.05), Fe (12.36; p<0.05), Cu (9.25; p<0.05), Zn (6.39; p<0.05), exchangeable acidity (25.66; p<0.05) across the ecological zones. Similarly, in the subsoil, soil pH, organic C, total N, available P, Ca, Mg, K, CEC, Pb, Mn, Fe, Cu, and Zn were significantly varied among the ecological zones.

Table 3: Pairwise t-test and Analysis of Variance of Physical Properties of Soil across the Ecological Zones

Soil Parameters	Topsoil Mean±SD	Subsoil Mean±SD	t- value	F Value Topsoil	F Value Subsoil
Soil Moisture (%)	19.38±7.9	19.66±8.4	0.405	38.89+	36.87+
Temperature (^oC)	27.16±0.6	27.31±0.6	1.621	2.06	2.66
Sand (%)	77.16±10.4	77.81±10.3	0.561	36.10+	15.33+
Silt (%)	11.91±5.5	11.35±6.1	0.576	11.05+	5.71+
Clay (%)	10.93±7.4	10.83±6.3	0.124	14.87+	30.46+
Bulk Density (g/cm^3)	1.46±0.1	1.45±0.1	0.435	0.27	1.47
Total Porosity (%)	44.50±2.9	45.31±2.7	1.203	0.64	2.63
Water Holding Capacity (%)	44.35±1.3	44.29±1.1	0.177	0.48	0.58

N=32 ,+ Significant at p<0.05

Table 4: Pairwise t-test and Analysis of Variance of Chemical Properties of Soil across the Ecological Zones

Soil Parameters	Mean±SD	Mean±SD	Pairwise T-Test	F Value Topsoil	F Value Subsoil
pH	4.88±0.4	4.93±0.5	2.760*	46.68+	50.39+
Organic C	3.57±2.1	3.02±2.0	2.183*	7.11+	5.20+
Total N	0.28±0.2	0.26±0.2	0.762	4.28+	7.08+
Available P	15.13±10.1	15.35±11.8	0.165	4.35+	5.91+
Ca	1.81±1.3	1.89±1.4	1.101	53.07+	70.78+
Mg	0.69±0.4	0.69±0.4	0.020	34.34+	26.58+
K	0.40±0.1	0.39±0.1	0.289	5.18+	7.95+
Na	0.28±0.1	0.27±0.1	0.787	1.32	1.39
CEC	6.56±3.5	6.22±2.9	0.974	15.76+	13.35+
Ex Acidity	3.39±3.8	2.96±3.0	1.210	25.66+	24.38+
Pb	8.13±2.0	7.89±1.8	0.711	0.92	3.93+
Mn	262.97±42.2	268.56±30.4	0.667	3.26+	4.40+
Fe	206.74±141.6	186.02±95.7	1.490	12.36+	8.40+
Cu	0.31±0.2	0.35±0.3	1.003	9.25+	4.72+
Zn	7.15±2.0	7.35±2.8	0.772	6.39+	8.23+

N=32 *****; + Significant at p<0.05

Discussion of Findings

The soil moisture in both topsoil and subsoil of the mangrove was the highest among the ecological zone and that of guinea savanna was the least. Much soil moisture in the topsoil of mangrove can be attributed to the topsoil that is loosely formed as sandy or clayey types (Hossain and Nuruddin, 2016) as the lighter coloured top soils are porous and facilitate water percolation and aeration during low tide (Hossain and Nuruddin, 2016). All the ecological zones are predominantly dominated by sand content although, sand contents in the mangrove were higher. The presence of higher sand content in the mangrove can be attributed to the dune ecology of this area which has been considerably disturbed by the removal of sand for building purposes which might have led to increased deposition of wind-blown sand into the mangrove area (Naidoo and Raiman, 1982). The bulk density in the four ecological zones was relatively high and this could be attributed to similar higher sand content in the particle size composition.

The variation in the total porosity could be attributed to bulk density in which an inverse relationship is maintained between them. Arshad (1996) noted that high bulk density is an indicator of low soil porosity and soil compaction. Surface crusting and compaction decrease porosity and inhibit water entry into the soil, possibly increasing surface runoff and erosion (McCauley *et al.,* 2005). The higher porosity of the topsoil under rainforest is similar to the findings of Aborisade and Aweto (1990).The slight variation in the water holding capacity can be due to the slight variation in the soil textural composition. Ability of soil to provide plants with adequate water is based primarily on its texture. If a soil contains many macropores, like coarse sand, it loses a lot of water through gravitational drainage (McCauley *et al.,* 2005). In addition and very importantly, the variation in the soil organic matter may cause varying levels of water holding capacity and porosity. The higher mean total N in mangrove contradicted the studies of Reich and Oleksyn, (2004); and Lovelock et al., (2007) which stated that mangrove soils are found nutrient limited, particularly in N and P.The soil moisture and soil temperature were higher in the subsoil than the topsoil across the ecological zones. It was reported that the soil below the surface are typically waterlogged having little aeration facility which reduces with depth but contain a lot of organic matter (Hossain and Nuruddin, 2016). Also, the soil moisture, sand, silt and clay were significantly varied between the topsoil and subsoil in the entire study area. Generally the soil pH in both topsoil and subsoil in the study area was acidic but less acidic in mangrove ecological zone. Organic C and total N were higher in the freshwater swamp, mangrove and rainforest. The variation in the Organic C and N could be attributed to different rates of litterfalls in these ecological zones. Guo-Jian Fen *et al.* (2004) reported that the rainforest has a greater carbon return through litterfall, which is beneficial to the increase of soil organic matter storage and the maintenance of soil fertility. Boley *et al*. (2009) also affirmed that surface soil nutrient enrichment through litterfall and root turnover increase soil organic matter. The mean organic C and total N were higher in the topsoil than the subsoil in the entire study area. The higher total N in the topsoil in the study area may be due to the progressive build-up of total nitrogen in the topsoil due to litter decomposition (Awotoye *et al*, 2011; Ichikogu, 2012), mineralization (Awotoye *et al*, 2011), external inputs which include nitrogen fixing plants (Fernandes *et al.,* 1997; Ichikogu, 2012) and atmospheric deposition (Schroth *et al*, 2001). Although, Kowal and Kassam (1978) stressed that the nitrogen status of the soil is closely associated with the soil organic matter as it (organic matter) is the major source of soil nutrients. Among the heavy metals investigated, Mn and Fe had higher concentrations in the ecological zones. Adefemi *et al.* (2007) reported that Fe occurs at high concentrations in Nigerian soils. Available P, CEC and exchangeable acidity were significantly higher in the freshwater swamp in both topsoil and subsoil. The concentrations of these soil chemical properties in the freshwater swamp could be attributed to the litterfall in the ecological zone.

Conclusion and Recommendations

The study can be concluded that the bulk density, total porosity and water holding capacity were slightly varied among the four ecological zones. Soil moisture was highest in the mangrove and the lowest was observed in the guinea savanna in both topsoil and subsoil. The organic C, total N, available P, exchangeable Mg and exchangeable acidity were considerably highest in the freshwater swamp while exchangeable Ca and Na were highest in mangrove in the topsoil. The concentrations of Pb, Cu, Zn and Fe were highest in the rainforest in the topsoil. The study therefore recommended that soil nutrients should be improved in guinea savanna possibly for the survival of soil microorganisms that can perform soil regeneration for the improvement of soil fertility while in the freshwater swamp, rainforest and mangrove, the soil nutrients must be protected. The physical soil properties especially sand, silt, and total porosity in the topsoil should be maintained in the ecological zones because of their major roles in supporting soil organism abundance in the study area. If these places are not too much exposed to erosion, the physical properties will be maintained and soil organism population livelihood and sustainability will also be realised.

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