COMPARATIVE ASSESSMENT OF SOIL PHYSICO-CHEMICAL PROPERTIES IN THE ECOLOGICAL ZONES OF BAYELSA STATE, NIGERIA

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ABSTRACT
The study examined the comparative assessment of soil physico-chemical properties in the ecological zones of Bayelsa State, Nigeria. Twenty 20m x 20m quadrats were delineated in the natural vegetation of the freshwater swamp (FWS) and mangrove (MG) ecological zones to collect soil samples and tree species. The soil samples were collected from the soil depths from 0-15cm, 15-30cm and 30-45cm and were analysed in the laboratory with standard methods. Descriptive and inferential statistics were used for data analysis. Findings showed that particle size composition (sand , silt, clay) were significantly higher in the freshwater than the mangrove. Similarly, soil temperature was significantly higher in the freshwater than mangrove. Findings also showed that Mg, and K showed significant variation between the freshwater and mangrove. It is recommended that more soil studies should be carried out in the study area and moreso, the bulk density and temperature should be closely and adequately monitored for the adequate retention of soil fertility for the survival of plants.

Keywords: Physico-chemical properties, Freshwater, Mangrove, Particle size composition, Bayelsa State.

1. INTRODUCTION
Soils have become one of the most endangered natural resources in the world under current pressures from land degradation and climate change (Titeux et al., 2016). Each year, an estimated 25-40 billion tons of fertile soil are lost globally (FAO and ITPS, 2015). Hence, improving soil health through sustainable land management should be a common goal for farmers and land managers, to protect, maintain and build soil which is their most vital resource. Soils are the major reservoir of C in terrestrial ecosystems, and soil C plays a vibrant role in influencing the global C cycle and climate change while regulating soil health and productivity (Mehra, Singh, Kunhikti and Cowie, 2018; Singh, Setia, Wiesmeier and Kunhikrishnan, 2018).
Soil health thus refers to the capacity of the soil to perform a range of agronomic and ecosystem functions, in order to sustain biological productivity, maintain environmental quality and promote plant and animal health (Kibblewhite, Ritz, and Swift, 2008; Lal, 2011; Mehra et al., 2018). Soils that are healthy occur when their biological, chemical, and physical characteristics are all adequate and are able to enable high yields of crops. As this occurs, roots are able to proliferate easily, bountiful water enters and stored in the soil, the plant has a sufficient nutrient supply, there are no harmful chemicals in the soil, and beneficial organisms are very active and able to keep potentially harmful ones in check as well as stimulate plant growth. Furthermore, soil physical health is largely determined by the impact of management and climate factors on

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SOM, soil structure, bulk density and air and water movement through the soil profile (Luo et al., 2017). One of the most important attributes of a healthy soil is soil structural stability, which affects the movement and management of water, oxygen and nutrients (Datiri and Lowery, 1991; Ussiri et al., 2009; Kladivko, 2001).

Thus, changes in soil structure which result directly from anthropogenic activities and indirectly from climate change can adversely influence soil physical health (Luo et al., 2017). Studies have demonstrated that poor soil structure due to anthropogenic activities such as continuous cultivation inhibits many plant processes (germination, root growth) (Turmel et al., 2015). Moreover, a boost in air and soil temperature unavoidably creates disparity in the soil-thermal regime, which is governed by the processes like evaporation, heat conduction and convective transfer via the movement of gas and water through the soil profile. This imbalance of soil-thermal regimes can impact important soil processes such as rapid decomposition of SOM and nutrient loss *via* volatilization (Qian et al., 2011). It is believed that the biological effectiveness proves that below ground organisms are significant in determining the functioning of ecosystems as they substantially regulate decomposition or nutrient mineralization/cycling. Hence, they partly determine plant growth and sustain the long-term productivity (Wolters, 2001; Rossi, Mathieu, Cooper and Grimaldi, 2006). As a result, soil organisms are increasingly considered as a resource to be managed and protected (Rossi et al., 2006). Soil is not a state factor for plant growth, as soil formation is influenced by plants (biota) climate, geology, topography and time (Fujii et al., 2018). Soil can influence plant physiological processes, while plants can also change soil processes, a concept known as plant-soil feedback. The cause-effect in plant-soil processes or plant-soil feedback are linked to soil chronosequences, plant impacts on soil processes, strategies of nutrient acquisition and utilization (allocation), and niche differentiation related to soil nutrients.

Soil is known for its huge spatial (vertical and even) and transient heterogeneity which leads to a wide scope of surface kinds, total and pore estimates and microclimates, and a scope of assets and asset apportioning in reality. This intricacy is a snag to the utilization of single measures (for example pH, natural matter substance) as comprehensively pertinent signs of soil wellbeing and environment work (Baveye et al. 2016), rather basic markers should be developing or possibly very much connected to basic systems. The actual climate can be considered as a format on which living beings and biological frameworks work; for some dirt living beings, particularly miniature organic entities, the design of the dirt pore network de-fines the powerful territory space in soil (Young and Ritz, 2000). The sum and nature of the pore space in soil are reliant on soil surface as well as on the collection of mineral particles and soil natural matter (SOM), which is, the development and adjustment of soil structure. Most soil organic entities have restricted movement limit (Fitter et al. 2005) and motility of many soil species is low contrasted with the size of asset inconsistency (Ettema and Wardle, 2002). Soil living beings likewise regularly enter inert or torpid states in negative circumstances, with the goal that variety is safeguarded much under outrageous circumstances; this is undifferentiated from the job of soil seed-banks in protecting plant variety (Ettema and Wardle, 2002). Henceforth, creatures' reaction to the actual climate might show designs that change among species and are obliged by the math of the climate (Williams, Marsh and Winter, 2002).

A few investigations have been done at various spatial and transient scales for recognizing the vegetative elements as well as the connections among various vegetation types and critical

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changes at worldwide and local level have been seen in environment as well as in vegetation cover. Under such circumstances, more consideration has been paid throughout the most recent a long time on the environment related investigations. Nonetheless, it is obvious that the vegetation is firmly interrelated with their general surroundings. Changes in various climatic boundaries could result to the arrangement and variety of vegetation cover at different levels.

They can be extreme and surprisingly unsafe on certain types of vegetations and can be minor on a few others. Thus, an equivalent consideration must be paid on the vegetation elements. All the more critically the connections that could exist among these interrelated parts must be recognized to make precise and sensible expectations on the changing states of the vegetation as well as the climatic boundaries. This will likewise give the chance to making prudent steps for limiting the potential dangers related with such changing states of environment as well as the biological systems. It is likewise expected that the provincial varieties of various climatic boundaries to be a lot bigger and consequently nitty gritty examinations on explicit issues must be done to get an unmistakable picture on these progressions at territorial scales. Current interests in the livability of the earth and climate have animated a large group of worldwide observing projects to analyze the potential results of varieties in prime environment boundaries, for example, precipitation, temperature barometrical gas focus, radiation levels, and land cover.

2. MATERIALS AND METHODS

The study was carried out in Bayelsa State, Nigeria. Bayelsa State is geographically located with latitude 4^{0}15'North and latitude 5^{0}23'South and longitude 05^{0}22' west and 06^{o}45' East. It shares boundaries with Delta State on the North, Rivers State on the East and the Atlantic Ocean on the West and South. The State has a land mass of 21, 110 Sq km/10,773 square miles. Bayelsa is a State in Southern Nigeria in the core Niger Delta region. The area lies almost entirely below sea level with a maze of meandering creeks and rivers in the south, all flow into the Atlantic ocean via the major rivers such as San Bartholomew, Brass, Nun, Ramos, Santa Barbara, St Nicholas, Sangana, Fishtown, Ikebiri creek, Middleton , Digatoro creek, Penington and Dobo (Figure 1).

The study area has the same weather condition like Port Harcourt as a region. The climatic condition is the tropical climate (Ologunorisa & Adejuwon, 2003). The months of February and March records the highest temperature of 33°C, while the months of January and December records the lowest temperature of 21°C. Temperature rises through the months of October, November and December. The monthly rainfall in the area is slightly predictable due to climate change in the world today, temporally rainfall decreases from the months of October to February which is the dry season (Ologunorisa and Adejuwon, 2003). The rainfall in the area is greatly influenced by the Inter Tropical Discontinuity (ITD), due to its location. Rainfall peaks in July and September with a little dry season in August (August break).The area experiences about 2476 mm of precipitation falls annually. There are three major soil groups identified in the Niger Delta, namely: the marine and fluvial marine sediments; the mangrove swamp alluvial soils; and freshwater brown loams and sandy loams. The "upland" area was originally occupied by rainforest which has been drastically modified by human activities. In most places, economic trees, particularly oil palm, have been preserved and thus the sobriquet for this vegetation as "oil palm bush." The riverine area is divided into three main hydro vegetation zones namely, the beach ridge zone, the saltwater zone and the freshwater zone. In terms of general surface features, the area is very unique, and falls within the coastal belt dominated by low lying coastal plain which belongs to the structural sedimentary formation of the recent Niger Delta. Umeuduji and Aisebeogun (1999) identified that the area is within the belt of fresh water raffia dominated wetlands with heights which vary between 10-25m above sea level. Five soil samples were collected from each 20m x 20m quadrat using soil auger at the depth of 0-15cm, and 15-30cm and 45-60cm. 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, 20 soil samples were collected from each 20m x 20m quadrat the depth of 0-15cm, 15-30cm and 45-60cm in each 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. Soil temperature was measured with soil thermometer *in situ* (Ochsner, 2008) while soil moisture was measured using gravimetric method (Su, Singh & Baghini, 2014). Soil pH was determined using saturated paste extract while organic carbon was determined by Walkey and Black's rapid titration method (Walkey & Black, 1934). Descriptive statistics was used to describe the mean values of the soil properties and pairwise t test was used to determine the significant variation in the soil properties between freshwater swamp and mangrove.

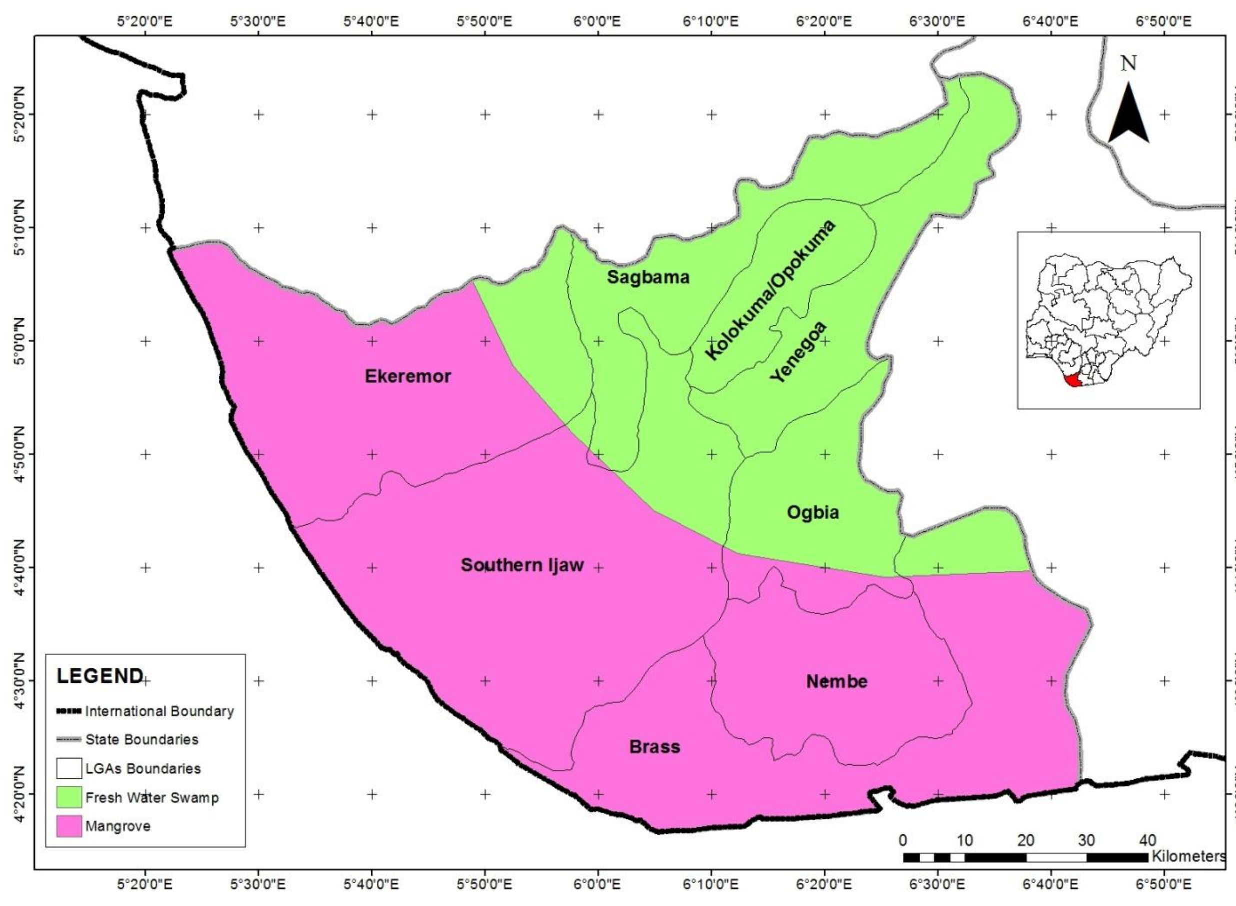

Figure 1: Ecological Zones of Bayelsa State

3. RESULTS AND DISCUSSIONS

Soil Physical and Chemical Properties in the Ecological Zones

The physical properties of soil at varying soil depths are shown in Table 1 while Table 2 shows the general descriptive statistics of soil physical properties. Sand content was highest in FWS zone (50.68%) at soil depth of 15-30cm and the lowest was observed also under the FWS zone (31.61%). Considering silt content, FWS zone recorded 52.99% (0-15cm), while M zone recorded 32.25% (0-15); FWS recorded 34.36% (15-30cm) while M zone recorded (32.59% (15-30cm); and 45.41% (30-45cm) under the FWS zone while M zone recorded 30.54% (30-45cm). Clay content was highest (28.38%) at soil depth of 30-45cm under the M zone and lowest (14.33%) at soil depth of 0-15cm under the FWS zone. The bulk density slightly varied in the sampled ecological zones (FWS and M), but FWS zone recorded the highest with mean value of 1.58 g/cm^3 at soil depth of 15-30cm and the least was observed in M zone (1.514 g/cm^3) at soil depth of 30-45cm. The porosity (%) and water holding capacity (%) varied slightly among the sampled ecological zones. However, soil porosity was highest in the M zone (47.47%). 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 M zone with the mean value of 43.27% at soil depth of 30-45cm. Soil moisture was highest in the FWS zone (79.71%) at soil depth of 30-45cm and the lowest was observed in the M zone (72.07%) at soil depth of 15-30cm. Temperature varied considerably in both sampled ecological zones but temperature was highest in FWS zone with a mean temperature of 29.09^{0}C at soil depth of 0-15cm. The general descriptive statistics of soil physical properties on Table 4.97 revealed that among the soil particles size distribution (sand, silt and clay), sand content (45.56%) recorded the highest under the M zone. Overall mean values for Bulk density and water holding capacity showed that they were slightly higher under the FWS zone. Overall mean Porosity (47.20%) was higher under the M zone which was attributed to the higher sand content in soil. Overall mean Temperature (26.40^{0}C) and soil moisture content (78.69%) were higher under the FWS zone.

Table 1: Descriptive Statistics of Soil Physical Properties across the Soil Depths in Different Ecological Zones

Soil Properties	Soil Depth	Freshwater	Mangrove
		Mean±SD	Mean±SD
Sand (%)	0-15	32.68±9.4	46.20±23.8
	15-30	50.68±11.4	49.39±18.9
	30-45	31.61±10.5	41.09±16.8
Silt (%)	0-15	52.99±9.0	33.25±11.6
	15-30	34.36±9.9	32.59±13.3
	30-45	45.41±8.5	30.54±10.7

Clay (%)	0-15	14.33±5.1	20.56±14.7
	15-30	14.97±4.1	18.02±7.6
	30-45	22.99±9.0	28.38±15.13
Bulk Density (gcm^3)	0-15	1.56±0.1	1.52±0.1
	15-30	1.58±0.1	1.54±0.1
	30-45	1.55±0.1	1.51±0.1
Water Holding Capacity (%)	0-15	42.45±0.7	41.87±0.7
	15-30	42.79±1.1	42.47±1.4
	30-45	43.06±9.0	43.27±1.4
Porosity (%)	0-15	46.52±0.9	47.47±1.5
	15-30	45.99±1.3	46.72±1.6
	30-45	45.91±0.4	47.42±1.5
Soil Moisture (%)	0-15	79.32±3.7	75.07±3.85
	15-30	77.04±4.8	72.07±5.9
	30-45	79.71±4.0	76.47±7.2
Temperature (°C)	0-15	29.09±0.9	26.33±0.8
	15-30	26.12±1.1	24.34±0.6
	30-45	23.98±1.1	22.57±1.4

N=20

Table 2: General Descriptive Statistics of Soil Physical Properties across the Soil Depths in Different Ecological Zones

Soil Properties	Freshwater	Mangrove
	Mean±SD	Mean±SD
Sand (%)	38.32±13.5	45.56±20.1
Silt (%)	44.25±11.3	32.12±11.8

Clay (%)	17.43±7.5	22.32±13.5
Bulk Density (gcm^3)	1.56±0.1	1.53±0.1
Water Holding Capacity (%)	42.77±1.0	42.54±1.3
Porosity (%)	46.14±0.9	47.20±1.6
Soil Moisture (%)	78.69±4.3	74.54±6.0
Temperature (°C)	26.40±2.4	24.41±1.8

N=60

The information for soil chemical properties across soil depths were displayed on Table 3 while Table 4 reveals the general statistics using their overall mean values in sampled ecological zones. The exchangeable acidity in the sub soil (15-30cm) was highest (0.47 Cmol/kg) in the FWS zone and the lowest (0.40 Cmol/kg) was also experienced under the FWS zone at soil depth of 30-45. The mean highest CEC for FWS zone was 15.16 Cmol/kg at soil depth of 15-30cm while the highest of 15.92 Cmol/kg was experienced under the M zone at soil depth of 30-45cm. The highest mean percentage concentration of organic C was 2.16% (0-15cm) in the FWs zone; while it was 2.12% in M zone at soil depth of 15-30cm. Similarly, total N was highest in the FWS zone (0.38%) at soil depth of 30-45cm and the least was found in M zone with mean value of 0.31% at soil depth of 30-45cm. Available P in the topsoil (0-15cm) was 4.33 mg/kg and the highest of 4.54 mg/kg in deeper subsoil (30-45cm) was also recorded under the FWS zone while the least of 0.77 mg/kg was recorded at subsoil (15-30cm) under the M zone. The mean value of Na varied across soil depths and ecological zones. The highest mean content of Na was 3.15 Cmol/kg at soil depth of 30-45cm and the least content of 0.35 Cmol/kg were recorded under the FWS zone. The exchangeable Ca was highest in the M zone (9.01 Cmol/kg) while the lowest was observed in FWS zone with mean content value of 7.40 Cmol/kg. Exchangeable Mg ranged from 2.72 Cmol/kg (0-15cm) to 4.25 Cmol/kg under the FWS zone. The range for Exchangeable Mg under the M zone was between 3.13 Cmol/kg and 3.61 Cmol/kg. Exchangeable K was highest (0.74 Cmol/kg) at soil depth 0-15cm and lowest at soil depth 30-45cm (1.24 Cmol/kg) under the FWS zone. However, the mean content values of Exchangeable K recorded minimum value of 0.56 Cmol/kg and 1.52 Cmol/kg under the M zone at soil depths of 15-30cm and 0-15cm respectively. In the topsoil (0-15cm), subsoil (15-30cm) and deeper subsoil (30-45cm) the soil pH was acidic across the ecological zones but more acidic (5.45) at soil depth of 30-45cm and also less acidic (5.74) at soil depth of 0-15cm under the M zone. The information for the general descriptive statistics of soil chemical properties across soil depths is displayed on Table 4.

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Table 3. Descriptive Statistics of Soil Physical Properties across the Soil Depths

Soil Properties	Soil Depth	Freshwater	Mangrove
		Mean±SD	Mean±SD
Exchangeable Acidity (Cmol/kg)	0-15	0.45±0.1	0.43±0.1
	15-30	0.47±0.1	0.44±0.2
	30-45	0.40±0.1	0.45±0.1
Cation Exchange Capacity (Cmol/kg)	0-15	11.80±3.6	15.27±8.1
	15-30	15.16±6.2	13.11±5.3
	30-45	13.30±3.8	15.92±11.0
Organic C (%)	0-15	2.16±0.9	1.92±1.0
	15-30	1.99±0.7	2.12±1.1
	30-45	1.79±0.8	1.86±0.9
Total N (%)	0-15	0.35±0.1	0.32±0.1
	15-30	0.36±0.1	0.34±0.2
	30-45	0.38±0.3	0.31±0.2
Available P (Cmol/kg)	0-15	4.33±1.0	1.34±0.8
	15-30	4.13±1.0	0.77±0.3
	30-45	4.54±0.9	0.94±0.9
Na(Cmol/kg)	0-15	3.15±0.1	2.12±1.6
	15-30	0.35±0.4	1.18±0.9
	30-45	0.50±0.3	2.42±2.3
Ca (Cmol/kg)	0-15	7.42±1.9	8.25±5.3
	15-30	7.40±1.7	7.80±4.6
	30-45	8.24±2.1	9.01±0.7
Mg (Cmol/kg)	0-15	2.72±1.1	3.33±1.9

	15-30	3.19±1.0	3.61±1.3
	30-45	4.25±1.8	3.13±1.2
K (Cmol/kg)	0-15	0.74±0.3	1.52±1.7
	15-30	0.79±0.4	0.56±0.4
	30-45	1.24±0.6	1.39±0.8
pH	0-15	5.57±0.2	5.74±0.3
	15-30	5.64±0.2	5.59±1.1
	30-45	5.59±0.4	5.45±0.6

N=20

Table 4: General Descriptive Statistics of Soil Physical Properties across the Soil Depths

Soil Properties	Freshwater	Mangrove
	Mean±SD	Mean±SD
Exchangeable Acidity (Cmol/kg)	0.44±0.1	0.43±0.1
Cation Exchange Capacity (Cmol/kg)	13.42±4.8	14.77±8.4
Organic C	1.98±0.8	1.97±1.0
Total N	0.36±0.2	0.32±0.1
Available P (Cmol/kg)	4.33±1.0	1.01±0.7
Na (Cmol/kg)	1.42±4.6	1.90±1.8
Ca (Cmol/kg)	7.69±1.9	8.35±5.7
Mg (Cmol/kg)	3.39±1.5	3.36±1.5
K (Cmol/kg)	0.93±0.5	1.16±15
pH	5.60±0.3	5.59±0.5

N=60

Variation in the soil physical and chemical properties among the soil depths and between the ecological zones

The computed ANOVA analysis for soil physical properties under the FWS zone is displayed on Table 5. The results showed that soil physical parameters among soil depths for water holding

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capacity (%) (F=1.897; p<0.05), bulk density (g/cm^3) (F=0.323; p<0.05), porosity (%) and soil moisture content (%) (F=2.393; p<0.05) were all not significant. However, there exist significant variations of soil physical parameters among soil depths for sand content (%) (F=20.979; p<0.05), silt content (%) (F=20.846; p<0.05), clay content (%) (F=11.134; p<0.05) and temperature (F=120.114; p<0.05).

The ANOVA statistics of soil chemical properties among soil depths in the FWS zone is displayed on Table 6. The results showed that variations in soil chemical properties among soil depths for Ex. Acidity (F=1.494; p<0.05), Na (F=2.163; p<0.05), CEC (F=2.558; p<0.05), pH (F=0.352; p<0.05), Organic C (F=1.080; p<0.05), Total N (F=0.208; p<0.05), Avail. P (F=0.784; p<0.05), and Ca (F=1.244; p<0.05) were not significant. However, variations in soil chemical properties among soil depths for Mg (F=6.346; p<0.05) and K (F=7.352; p<0.05) were significant under the FWS zone.

Table 5: ANOVA of Physical Soil Properties among the soil depths in Freshwater ecological zone

Soil Parameters		Sum of Squares	df	Mean Square	F	Sig.
Water Holding Capacity	Between Groups	3.737	2	1.869	1.897	0.159
	Within Groups	56.136	57	.985		
	Total	59.873	59			
Sand	Between Groups	4590.937	2	2295.468	20.979	0.000*
	Within Groups	6236.799	57	109.418		
	Total	10827.736	59			
Silt	Between Groups	3512.653	2	1756.326	20.846	0.000*
	Within Groups	4802.317	57	84.251		
	Total	8314.970	59			
Clay	Between Groups	931.504	2	465.752	11.134	0.000*
	Within	2384.342	57	41.831		

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	Groups					
	Total	3315.846	59			
Bulk Density	Between Groups	.010	2	.005	.323	0.725
	Within Groups	.853	57	.015		
	Total	.863	59			
Porosity	Between Groups	4.396	2	2.198	2.430	0.097
	Within Groups	51.548	57	.904		
	Total	55.944	59			
Soil moisture	Between Groups	83.196	2	41.598	2.393	0.100
	Within Groups	990.758	57	17.382		
	Total	1073.954	59			
Temperature	Between Groups	263.473	2	131.737	120.114	0.000*
	Within Groups	62.516	57	1.097		
	Total	325.989	59			

N=60

***Significant at p<0.05**

Table 6: ANOVA of Chemical Soil Properties among the soil depths in Freshwater ecological zone

Soil Parameters		Sum of Squares	df	Mean Square	F	Sig.
Ex. Acidity	Between	.052	2	.026	1.494	.233

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	Groups					
	Within Groups	.992	57	.017		
	Total	1.044	59			
Na	Between Groups	89.501	2	44.750	2.163	.124
	Within Groups	1179.080	57	20.686		
	Total	1268.581	59			
CEC	Between Groups	113.322	2	56.661	2.558	.086
	Within Groups	1262.667	57	22.152		
	Total	1375.990	59			
	Within Groups	62.516	57	1.097		
	Total	325.989	59			
pH	Between Groups	.056	2	.028	.352	.705
	Within Groups	4.514	57	.079		
	Total	4.570	59			
Organic C	Between Groups	1.342	2	.671	1.080	.347
	Within Groups	35.422	57	.621		
	Total	36.763	59			
Total N	Between Groups	.021	2	.011	.208	.813

	Within Groups	2.928	57	.051		
	Total	2.949	59			
Avail. P	Between Groups	1.633	2	.817	.784	.461
	Within Groups	59.364	57	1.041		
	Total	60.997	59			
Ca	Between Groups	9.170	2	4.585	1.244	.296
	Within Groups	210.073	57	3.685		
	Total	219.242	59			
Mg	Between Groups	24.461	2	12.231	6.346	.003*
	Within Groups	109.857	57	1.927		
	Total	134.319	59			
K	Between Groups	3.093	2	1.547	7.352	.001*
	Within Groups	11.990	57	.210		
	Total	15.083	59			

N=60

4.CONCLUSION AND RECOMMENDATIONS

The study concluded that the soil physico-chemical properties such as sand content, silt content, clay content, soil temperature, Mg and K varied significantly between freshwater and mangrove ecological zones. Based on the findings, the study recommended that more soil studies are required in between the freshwater and mangrove ecological zones. Moreso, the bulk density and temperature that were higher in the freshwater should be monitored adequately for the purpose of retention of soil fertility.

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