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ASSESSMENT OF PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN KWARA STATE POLYTECHNIC FOREST RESERVES

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ABSTRACT

The different features of soil greatly affect the flora and vegetative diversity of a forest. The soil physico-chemical characteristics in the Kwara State Polytechnic Forest Reserves were evaluated. Three composite soil samples were collected randomly from different locations at the depth of 0-20 cm, 20-60 cm, and 60-100 cm using a soil auger. The following methods were used; soil texture by hydrometer, infiltration rates and capacities by double ring infiltrometer, temperature by thermometer, and moisture content by digital moisture meter. Physical analysis results revealed that the soil in the study area is sandy loam, average infiltration rate is 96.9 mm/hr and infiltration capacities (K) are generally high and varied from 0.00956 to 0.0104 cm/s. The moisture contents for the sampling locations (Points A, B, and C) are; 1.08 %, 1.05%, and 1.09%, respectively. Similarly, soil temperatures are; 6.7, 5.4, and 7.8 ºC, respectively. Chemical analysis results revealed that the soil pH was moderately to slightly acidic and the average organic carbon ranged from 0.142 - 0.267 %. The phosphorous is high ranging from 20.276 to 28.342 mg/l and sodium is generally low ranging from 0.156 to 0.653 me/l. Exchangeable sodium percentage (ESP) ranged from 5.90 to 10.0 % and calcium is generally moderate from 4.36 to 6.22 me/l. Magnesium has been the dominant cation ranging from 1.16 to2.26 me/l. The organic matter is moderate ranging from 0.133 - 0.165% and the cation exchange capacity (CEC) ranged from 4.76 to 5.52me/l. Therefore, soil's physical and chemical properties are dominant factors influencing the extent of the decomposition process. Thus, the forest reserves serve as soil protection and promote soil fertility to support flourishing vegetation.

Keywords:*Soil, Forest reserves, Physical properties, Chemical properties, Fertility*

INTRODUCTION

It is impossible to overstate the ecological impact that forest reserves and the surrounding ecosystem have on soil fertility. According to Augusto *et al.* (2002), the idea of soil fertility can be connected to the physical, biological, chemical, climatic, and geological features of the site as well as human activities like farming, building, erosion, deforestation, and overexploitation. There has been extensive research on the effects of trees on soil formation and nutrient cycling, including weathering, fall litter and nutrient uptake, leaching, infiltration, erosion, and so forth (Binkley *et al.*, 1992).

Understanding the physical, chemical, and biological characteristics of soils makes it easier to relate those characteristics to the ecological needs of various species and gives crucial information regarding the soil's fertility (Spârchez *et al.*, 2013). These elements support the stability and well-being of forests and provide a foundation for improved decision-making in forest planning.Both the physical characteristics and the nutrients of a soil determine its fertility. Since soil fertility is the capacity of the soil to meet the needs of plants, the concept of soil fertility should be expanded to include the productive, environmental, and socio-economics of the people around the forest area (Kiryushin, 2007). Trophicity is a key component in determining soil fertility and is determined based on specific physical and chemical qualities (Târziu and Spârchez, 2013).

Soil is a dynamic zone made up of liquid, gaseous substances, rocks and organic particles sustained by physical, chemical, and biological processes (Isah *et al.,* 2014). The type of vegetation that develops on soil, however, can be significantly influenced by a variety of soil properties, such as depth, consistency, temperature, nutrient contents, moisture content, permeability and porosity (Boyle and Powers, 2013).

Water, wind, temperature changes, gravity, chemical interaction, topography, vegetation, living organisms, and pressure differences are the geologic and geomorphologic factors that have the greatest impact on soils; however, living organisms, such as vegetation, also play a major role in many processes involved in soil formation, such as organic matter accumulation, profile mixing, and biogeochemical nutrient cycling (Boul, 1990).

One of the most important processes in regulating the cycling of nutrients and creating soil organic matter is decomposition. In tropical forest ecosystems, the decomposition of litter is what maintains natural systems or soil fertility. The biota of the forest primarily obtains its energy from the degraded litter, which also serves as the foundation for numerous food chains in tropical forests (Boul, 1990).

Given their interdependence and reliance on the ecosystem at large, the interaction between soil and trees is crucial (FAO, 2015). Soil provides the water, nutrients, and support that trees require to flourish, and trees and other plants play a significant role in the production and enrichment of soil (FAO, 2015). Differences in soil characteristics can result from the various tree species' capacities for nitrogen uptake and return to the soil (Rawat, 2005).

Regular deforestation for farming and other human activities reduces the amount of vegetation cover, which exacerbates soil erosion processes, particularly in the study area. This may eventually result in water logging which may in turn cause leaching of nutrients under the plant's root zone, making the soil deficient in some nutrients (Oyebode *et al.,* 2013).

Increased soil organic matter can improve soil structure and nutrient cycling through biological nitrogen fixation, phosphorus solubilization, and breakdown of organic materials in rhizosphere and non-rhizosphere zones of plants (Voroney, 2007; Schoenholtz *et al.,* 2000). Similarly, the ability of various tree species to recycle nutrients back into the soil can lead to changes and enhancements in the characteristics of the soil (Rawat, 2005).

Regular soil quality monitoring is essential to the environment's and the natural forest's sustainability. Thus, the goal of the study is to assess the fertility and productivity state of the soil in Kwara State Polytechnic Forest Reserve by examining the physico-chemical properties of soil inside the natural forest ecosystem at three distinct soil levels (0-20, 20-60, and 60-100 cm).

MATERIALS AND METHODS

Description of the Study Area

The study area is located at the South East Wing of the Kwara State Polytechnic, Ilorin, main campus, in Moro Local Government Area of Kwara State, Nigeria. It is approximately located between latitude 08^0 33′ 16.4″ N, longitude 04^0 38′ 04.2″ E and latitude 08^0 33′ 38.4″ N and longitude 04^0 38′ 20.6″ E of Greenwich Meridian. It is situated at kilometer 10 off old Ilorin- Jebba road. The Polytechnic entrance is between Elekoyangan and Oke-Ose village along the road. The Polytechnic land was carved out of the present Moro Local Government area of Kwara State, Nigeria. The Polytechnic hasa boundary with Ilorin East Local Government. Figure 1 is a satellite imagery showing the study area.

Figure 1:Satellite imagery showing the study area.

Source: www.Googlemap.com

Soil Sampling Method

Three composite soil samples were collected randomly from different locations at the depth of 0-20cm, 20-60cm, and 60-100cm using a soil auger. Bulk soil samples were taken into polythene bags and labeled accordingly. The collected soil samples were air-dried, gently crushed and sieved through 2 mm mesh for laboratory analysis. The undisturbed soil samples were collected using core cutters and sealed immediately on both edges with candle wax melted on the field to prevent loss of moisture.

2.3 Soil Physical Analysis

The following methods were employed for physical analysis:

(i) The particle size analysis was done using sieves of varying diameters, as given by ASTM E11.

(ii)The available soil moisture content was determined using a digital moisture Analyser.

(iii) The soil temperatures were observed on the field using a Thermometer.

(iv) Infiltration test was conducted using double ring infiltrometer.

Soil Chemical Analysis

The following methods were employed for chemical analysis:

(i) Soil pH was determined by pH meter in soil-water and soil-KCL filtrates.

(ii) Cation Exchangeable Capacity was determined titrimetrically, following sequential leaching with ammonium acetate, 95% ethanol and potassium chloride; and distillate collected over 2%.

(iii) Exchangeable Sodium Percentage (ESP) was observed by dividing total exchangeable sodium by the cation exchange capacity multiplied by 100.
(iv) Organic carbon (OC) expressed in percentage was determined using the Walkley-Black wet digestion method.

(v) Organic Matter (OM) in percentage was done by calculation using Equation1:

$$OM = OC \times 1.723 \quad \text{Eqn. (1)}$$

(vi) Calcium and Magnesium were determined using Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

Results of Soil Physical Analysis

The physical parameters evaluated include: soil texture, soil infiltration rates, soil temperature and available soil moisture content.

Result of Soil Texture Determination

The result of soil particle size analysis at the depths of 0-20cm, 20-60cm and 60-100cm are shown in Table 1, 2 and 3, respectively. Results of the soil particle size analysis revealed that soil in the study area is sandy loam, using textural classification triangle chart.

Table 1: Particle size analysis at soil depth 0-20cm

S/N	Sieve size (mm)	Mass of Empty sieve	Mass of Sieve and Soil	Individual Mass Retained	Individual Percent Retained	Cumulative Mass Retained	Cumulative Percent Retained	Calculated Percent Passing	Reported Percent Passing
1	12.5	553.0	482.0	129.0	25.4	129.0	25.4	74.6	75
2	10.0	380.0	424.0	44.0	8.7	173.0	34.1	65.9	66
3	6.7	430	507.0	77.0	15.2	250.0	49.1	50.9	51
4	4.75	515.0	567.0	52.0	10.3	302.0	59.4	40.6	41
5	2.36	473.0	558.0	85.0	16.8	381.0	76.2	23.8	24
6	2.00	478.0	491.0	13.0	2.6	400.0	78.8	21.2	21
7	1.00	522.0	570.0	48.0	9.5	448.0	88.3	11.7	12
8	600um	340.0	355.0	15.0	3.0	463.0	91.3	8.7	9
9	500um	395.0	420.0	25.0	4.9	488.0	96.2	3.8	4
10	300um	375.0	385.0	10.0	2.0	498.0	98.2	1.8	2
11	Pan	311.0	320.0	9.00		507.0			
				507.0					

Table 2: Particle size analysis at soil depth 20-60cm

S/N	Sieve size (mm)	Mass of Empty sieve	Mass of Sieve and Soil	Individual Mass Retained	Individual Percent Retained	Cumulative Mass Retained	Cumulative Percent Retained	Calculated Percent Passing	Reported Percent Passing
1	12.5	353.0	445.0	92.0	18.5	92.0	18.5	81.5	82
2	10.0	380.0	480.0	50.0	10.1	142.0	28.6	71.4	71
3	6.7	430	520.0	90.0	18.1	232.0	46.7	53.3	53
4	4.75	515.0	527.0	112.0	22.5	344.0	69.2	30.8	31
5	2.36	423.0	581.0	108.0	21.7	452.0	90.9	9.1	9
6	2.00	428.0	489.0	11.0	2.2	463.0	93.1	6.9	7
7	1.00	522.0	550.0	28.0	5.6	491.0	98.7	1.3	1
8	600um	340.0	343.0	3.0	0.6	494.0	99.3	0.7	1
9	500um	395.0	396.0	1.0	0.2	495.0	99.5	0.5	1
10	300um	375.0	375.0	1.0	0.2	496.0	99.7	0.3	0.3
11	Pan	311.0	312.0	1.0		497.0			
				497.0					

Table 3: Particle size analysis at soil depth 60-100cm

S/N	Sieve size (mm)	Mass of Empty sieve	Mass of Sieve and Soil	Individual Mass Retained	Individual Percent Retained	Cumulative Mass Retained	Cumulative Percent Retained	Calculated Percent Passing	Reported Percent Passing
1	12.5	353.0	433.0	80.0	16.7	80.0	16.7	83.3	83
2	10.0	380.0	400.0	20.0	4.2	100.0	20.9	79.1	79
3	6.7	430	490.0	60.0	12.5	160.0	33.4	66.6	67
4	4.75	515.0	569.0	54.0	11.3	214.0	44.7	55.3	55
5	2.36	473.0	629.0	165.0	32.6	370.0	77.3	22.7	22
6	2.00	428.0	535.0	57.0	11.9	427.0	89.2	10.8	11
7	1.00	522.0	569.0	47.0	9.8	474.0	99.0	1.0	1
8	600um	340.0	342.0	2.0	0.4	476.0	99.6	0.6	1
9	500um	385.0	396.0	1.0	0.2	477.0	99.8	0.4	0.4
10	300um	375.0	376.0	1.0	0.2	478.0		0.2	0.2
11	Pan	311.0	312.0	1.0		479.0			
				479.0					

S/N	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class (USDA)
1	0-20	80	12	8	Sandy Loam
2	20-60	82	10	8	Sandy Loam
3	60-100	79	11	10	Sandy Loam

Table 4: Average particle size distribution of the soil

This indicates that the soil is generally very light-textured with sand percentage averaging more than 80% and loam is 20%. The particle size distribution of the soils is shown in Table 4. The Therefore, the soils appear moderately suitable for irrigation, but may be drought prone.

Result of Soil Infiltration Rate and Capacity

The result of infiltration rate test is shown in Table 5. The estimated average infiltration rate of the soil in the study area is 96.9mm/hr.

The values of infiltration capacities (K) were generally high and varied from 0.00956cm/s to 0.0104cm/s. According to Shoeneberger *et al.* (2002) a coarse sandy soil with (K) value of 10^{-2} cm/s would have enormous infiltration capacity of nearly 10m/day while a fine loam soil with a (K) value of 10^{-4} cm/sec would have only about 10 cm/day.

Result of Soil Moisture Content and Temperature

The results of moisture contents for sampling points (A, B, and C) around the study area are; 1.08 %, 1.05%, and 1.09%, respectively. The available soil moisture contents obtained is low for point A, B, and C. The low percent of soil moisture ranged from 1.05 to 1.09% and it is an indication that enough moisture is not readily available to support plant growth which may reduce plant growth. The field capacity, permanent wilting point and available water content are called the soil moisture characteristics.

Table 5: Soil Infiltration Rate

1 Reading on the clock (hr min sec)	2 Time difference (min)	3 Cumulative time (min)	4 Water level Before filling (mm)	Readings After filling (mm)	5 Infiltration (mm)	6 Infiltration Rate (mm/min)	7 Infiltration rate (mm/hour)	8 Cumulative Infiltration (mm)
2 04 0	Start = 0	Start = 0	-	19	(19-15.3)3.7	(3.7/2)1.85	111	Start = 0
2 06 0	2	(2+0)2	15.3	20	(20-13)7	(7/5)1.4	84	(3.7+0)3.7
2 11 0	5	(7+2)7	13	18	(18-07)11	(11/10)1.1	66	(3.7+7)10.7
2 21 0	10	(10+7)17	07	18	(19-6)13	(13.2/15)0.88	52.8	(10.7+11)21.7
2 36 0	15	(17+15)32	4.8	19	(19-2)17	(13/20)0.65	39	(21.7+13.2)34.9
2 56 0	20	(32+20)52	06	19	(19-5)14	(17/24)0.7	43	(34.9+13)47.9
3 20 0	24	(52+24)76	02	19	(19.8-7)12.8	(14/30)0.5	28	(47.9+18)64.9
3 50 0	30	(76+30)106	05	19.8		(12.8/28)0.5	27.4	(64.9+14)74.9
4 20 0	28		07					(74.9+12)96.9

Soil moisture content is a portion of water which is easily extracted by the plant and it is about 75% of available water in the soil (FAO, 1985).The observed soil temperatures for sampling points (A, B, and C) around the study area are; 6.7 ºC, 5.4 ºC, and 7.8 ºC, respectively, and are moderately suitable for plant growth.

Table 6: Results of the selected average soil chemical properties

S/N	Parameter	0-20	20-60	40-100
1	pH	6.52	5.30	6.87
2	Mg^{++} (me/l)	1.36	1.16	2.26
3	Ca^{++} (me/l)	5.25	4.36	6.22
4	Na^{+} (me/l)	0.25	0.16	0.65
5	OC (%)	0.23	0.14	0.27
6	OM (%)	0.17	0.16	0.13
7	P (mg/l)	28.34	26.06	20.28
8	ESP (%)	10.00	9.11	5.90
9	CEC (me/l)	5.34	4.76	5.52

Table 7: Soil pH ranges

S/N	Ranges	pH
1	Strongly acidic	Below 5.1
2	Moderately acidic	5.2-6.0
3	Slightly acidic	6.1-6.5
4	Neutral	6.6-7.3
5	Moderately alkaline	7.4-8.4
6	Strongly alkaline	Above 8.5

Results of Chemical Analysis

The results of the chemical analysis are presented in Table 6. Soil pH is a measure of soil acidity and alkalinity. Soil pH on the field was moderately to slightly acidic as given by Hert *et al.* (1999) in Table 7. It ranged from 5.30 to 6.87 which indicates a decrease from 0 – 20 to 20 – 60 cm soil depth and subsequently tending towards neutral. In Figure 2, minimum and maximum soil pH values are 5.30 and 6.87. According to the United States Department of Agriculture (USDA), too high or too low soil pH leads to deficiency of many nutrients, decline in microbial activities, decrease in plant yield, and deterioration of soil health. Therefore, the soil is thus suitable for plant growth.

The average organic carbon ranged from 0.142-0.267% of the entire soil nutrients relating to soil fertility. According to Velayutham (2006), the organic carbon in the soil is considered high if it is within the range of 0.96-1.08%. It is observed from Figure 3 that the level of organic carbon has decreased from the surface depth (0 – 20cm) to the second depth (20-60cm) and sharply increased from the second depth (20 – 60cm) to the third depth (60 – 100cm) of the soil depths.

Phosphorus is an essential macro-nutrient that is relatively needed by crops in large quantities for proper growth and development. The different levels of soil phosphorous on the soil at three depths are shown in Figure 4. The available phosphorous content of the soil is high and larger from 20.276 to 28.342mg/l. However, the soil will be good for crops that require much phosphorus. Sodium, which determines the sodicity status of soil is generally low and ranges from 0.156 to 0.653me/l. It is observed from Figure 5 that the level of sodium slightly decreased from the soil surface depth (0 – 20cm) downward to the second depth (20-60cm) and also slightly increased to the third depth (60 – 100cm). The low sodium level in the soils indicates a non-sodic status of the soils and is thus good for irrigation (Joseph *et al.*, 2014).

Exchangeable sodium percentage (ESP) gives the measure of the potential sodium problem and is the percentage of sodium ions out of the total base cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) Marx *et al.* (1997). ESP value of the soil ranged from 5.90 to 10.0%. It slightly decreased from the soil surface depth (0-20cm) to the second depth (20-60cm) and decreased sharply to the third depth (60 – 100cm) as shown in Figure 6. However, the value of ESP has not exceeded 10% which could result in problems on the soil. The implication of a high ESP value on the soil is soil deterioration and unhealthy soil conditions as stated by Marx *et al.* (1997). Excessive sodium levels occurred in the study area resulting from irrigation water with high sodium content.

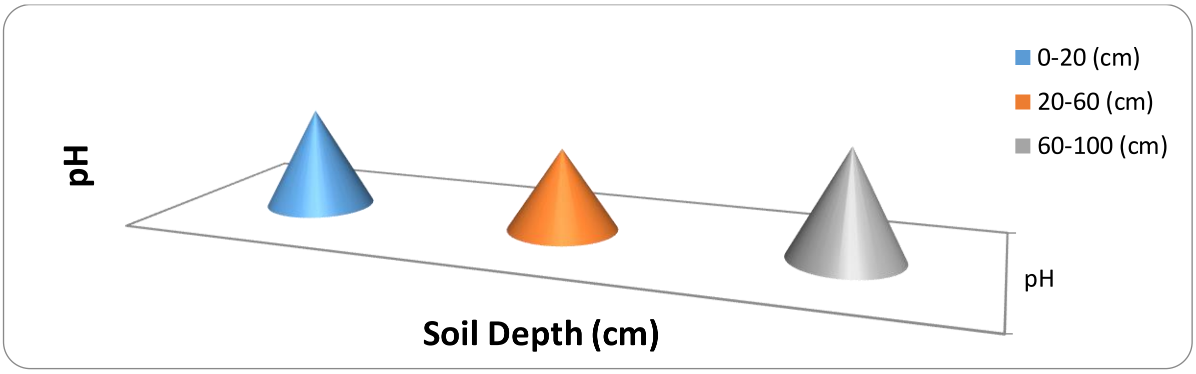

Figure 2: The soil available pH at three depths

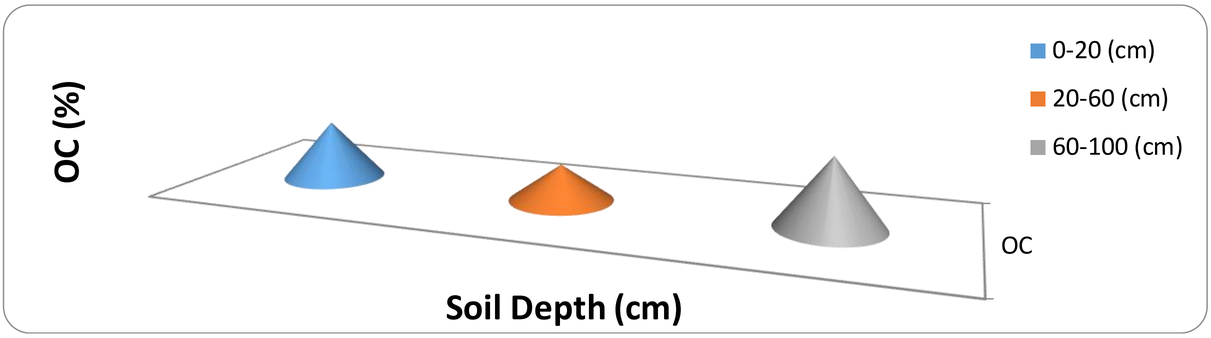

Figure 3: The soil organic carbon at three depths

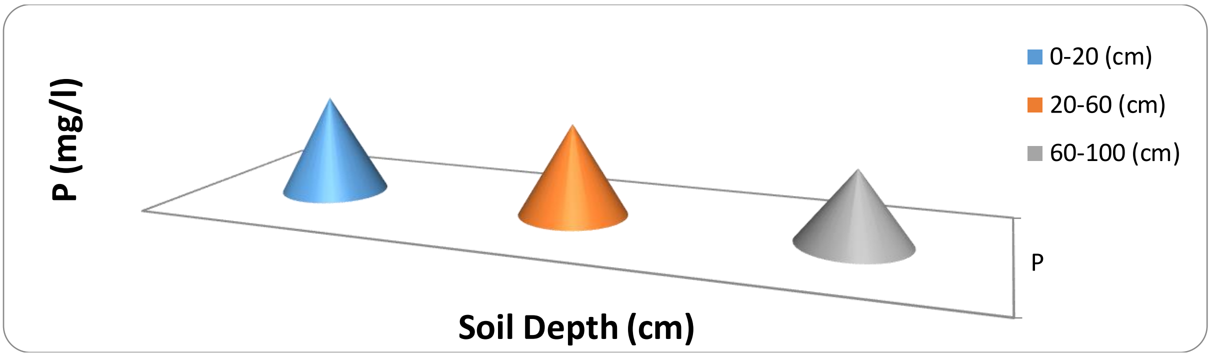

Figure 4: The soil phosphorous at three depths

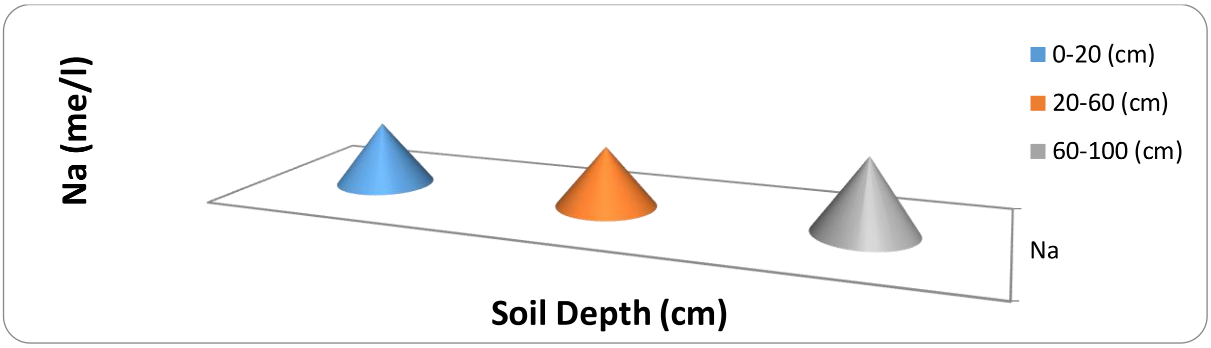

Figure 5: The soil sodium at three depths

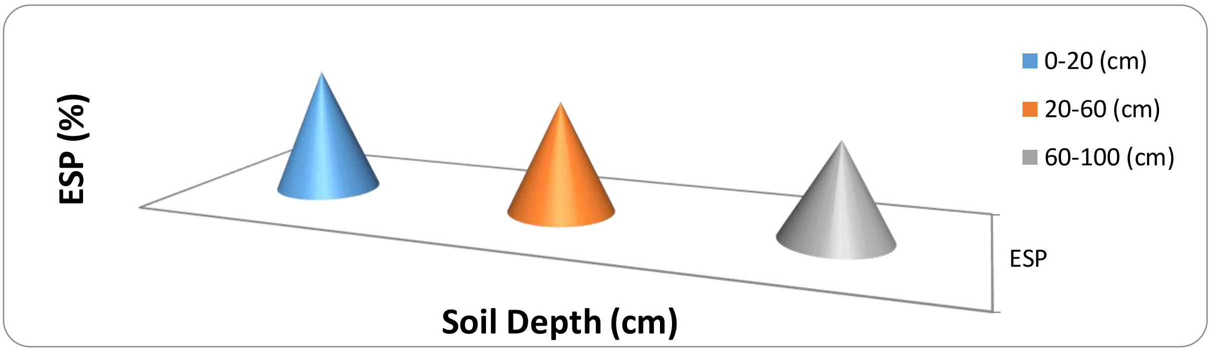

Figure 6: The soil ESP at three depths

The calcium in the soil of the study area is generally moderate and ranges from 4.36 – 6.22 me/l. Magnesium ranged from 1.16 – 2.26 me/l and was the dominant cation. It can be deduced from Figure 7 that there is a decrease in the calcium level from the soil surface depth to the second depth (20 – 60cm) and subsequently increased to the third depth (60 – 100cm). The decrease may be aresult of the leaching of the element during irrigation. This increase could be related to the increase in pH observed which tends towards moderate to slightly acidic. It indicates that irrigation has led to an increase in the calcium level of the soil.

In Figure 8, the magnesium level slightly decreases from the soil surface depth (0 – 20cm) to the second depth (20-60cm) and increases sharply from the second depth to the third depth (60 – 100cm). Magnesium is one of the secondary macronutrients required by plants, its deficiency causes leaf yellowing with brilliant tints (Yin, 2008). The organic matter of the soil is moderate ranging from 0.133 - 0.165% due to the rapid rate of organic matter decomposition as a result of available moisture during irrigation.

Figure 9 shows a decline in the organic matter level of the soil at the soil surface depth. The soil is considered moderately suitable for irrigation due to the moderate organic matter contents of the soil. Cation exchange capacity (CEC) is a measure of soil capacity to retain and release elements such as Ca, K, Mg, and Na (Marx *et al.*, 1999). It is used as one way of estimating soil fertility and a good indicator of soil quality and productivity. It is observed that the CEC value has increased from the soil surface depth (0 – 20cm) to the second depth (20 – 60cm) and a rapid decrease occurred from the second depth to the third depth (60 – 100cm) as shown in Figure 10. It ranged from 4.76 to 5.52me/l. Soils with higher value of CEC are considered fertile while soils with lower value of CEC are considered as non-fertile. The marked increase from the second depth (20 – 60cm) to the third depth indicates that irrigation has contributed to an increased level of CEC. Thus, soil currently falls within low to medium levels as given by Edmeades *et al.* (1998).

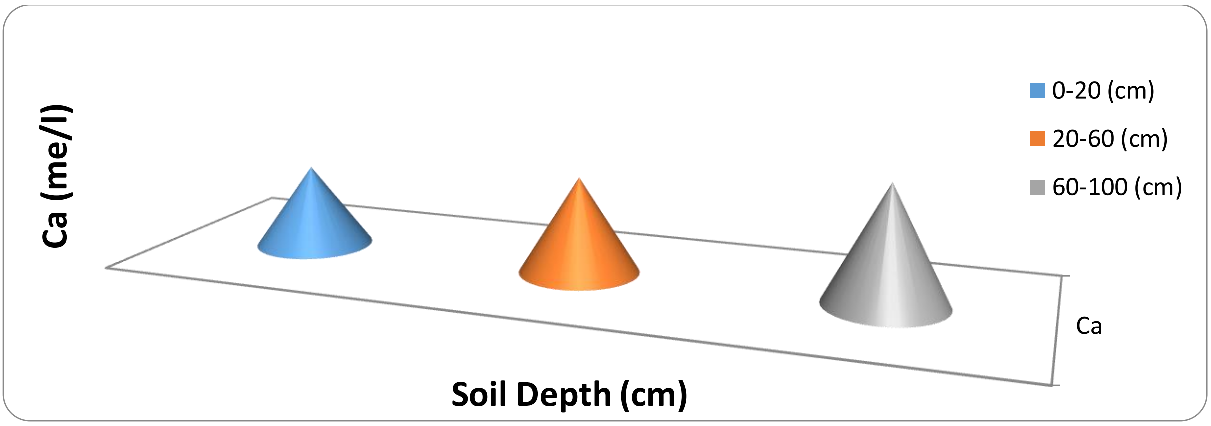

Figure 7: The soil calcium at three depths

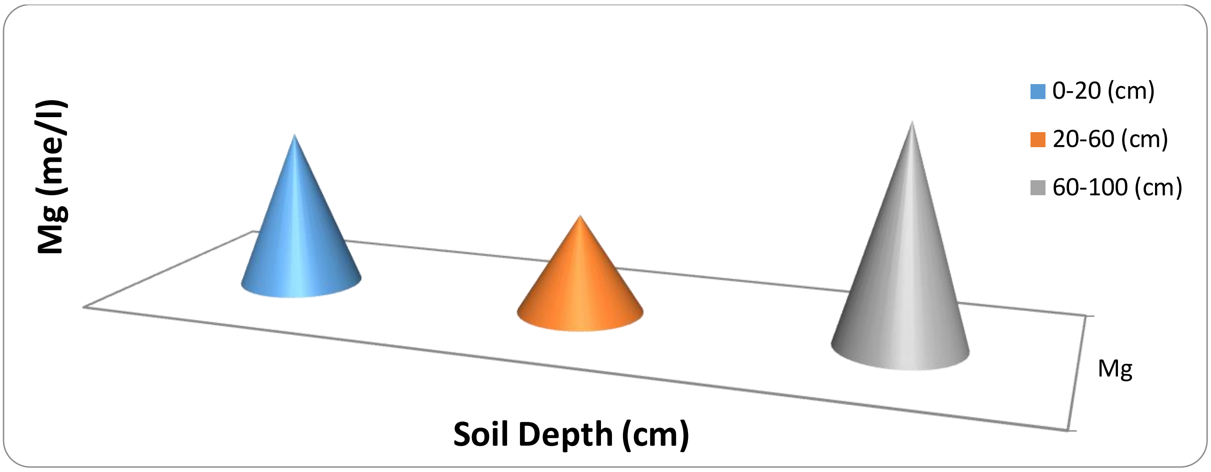

Figure 8: The soil magnesium at three depth

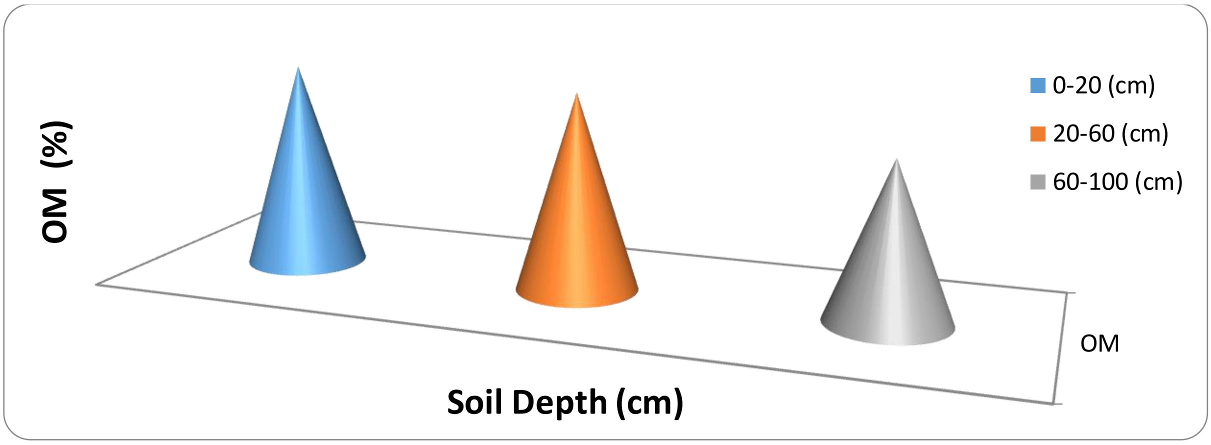

Figure 9: The soil organic matter at three depths

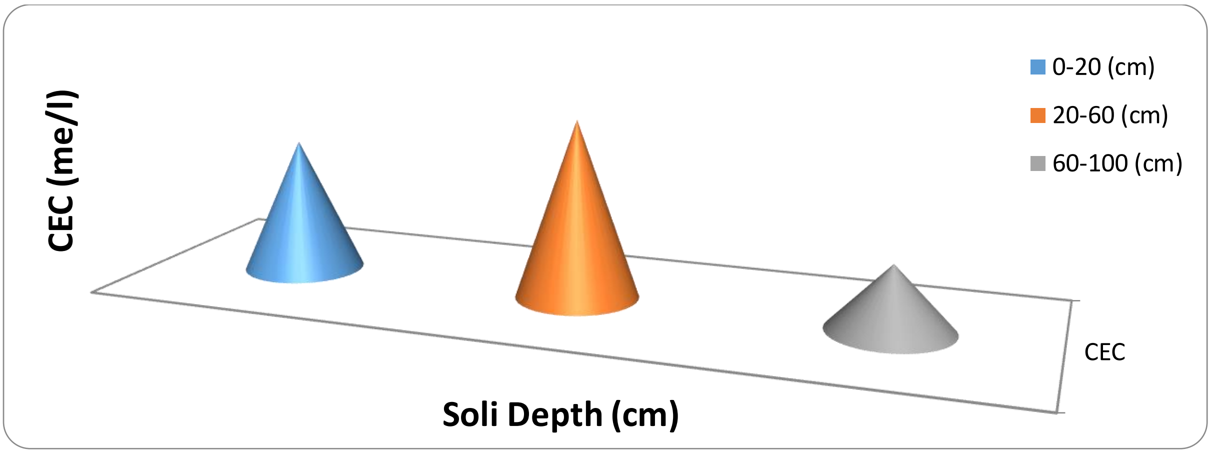

Figure 10: The soil CEC at three depths

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions were drawn from the study:

(i) There exists a high level of macro-nutrients such as phosphorous, calcium and CEC in the soil of the study area. The high levels may be detrimental to soil and plant growth.

(ii) The soil of the study area is predominantly sandy loam and the soil has a high value of infiltration capacity with low soil moisture content.

(iii) The study showed that soil texture is one of the most important factors influencing the physical and chemical properties of the soil.

(iv) The relationships of organic carbon (OC) and organic matter (SOM) with other determined parameters in the studied soils indicated them as important soil nutrients.

(v) Thus, the forest reserve serves as protection for the soil as well as promoting the fertility and productivity of the soils to support a flourishing vegetation type in the area.

Recommendations

The following recommendations were drawn from the conclusions:

(i) A periodic test has to be conducted to ascertain any changes in values obtained.

(ii) Careful selection of crop and management alternatives is required if full yield potential is to be achieved.

(iii) A Cashew plantation should be established in the study area and this will enhance income generation for the Kwara State Polytechnic, instead of leaving the land fallow as a hideout as the case is in the current situation.

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