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ASSESSING SOIL CHARACTERISTICS AND THEIR SUITABILITY FOR AGRICULTURAL PRODUCTION IN MALETE, KWARA STATE, NIGERIA

by

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Abstract
The different features of soil greatly affect the flora and vegetative diversity of agricultural productivity. The physical and chemical characteristics of soils in Malete area of Kwara State, Nigeria were assessed for their suitability for agricultural production. Three composite soil samples were collected randomly from different locations at the depth of 0-20cm, 20-60cm and 60-100cm using soil auger. The physical parameters evaluated includes soil texture using hydrometer, soil infiltration rates and capacity by double ring infiltrometer, soil temperature using soil thermometer and available soil moisture content by digital soil moisture meter. Results of the soil particle size analysis revealed that soil in the study area is sandy loam, using textural classification triangle chart. This indicates that the soil is generally very light-textured with sand percentage averaging more than 80% and loam is 20%. The estimated average infiltration rate of the soil in the study area is 96.9mm/hr and the values of infiltration capacities (K) were generally high and varied from 0.00956cm/s to 0.0104cm/s. The results of moisture contents for the sampling location points (Point A, B and C) around the study area are; 1.08 %, 1.05% and 1.09% respectively. Similarly, the observed soil temperatures are 6.7ºC, 5.4ºC and 7.8ºC respectively. Chemical analysis results revealed that the soil pH was moderately to slightly acidic and it ranged from 5.30 to 6.87. The average organic carbon ranged from 0.142-0.267% of the entire soil nutrients relating to soil fertility. The available phosphorous content of the soil is high which ranged from 20.276 to 28.342mg/l. The sodium status of the soil is generally low which ranged from 0.156 to 0.653me/l. The exchangeable sodium percentage (ESP) value of the soil ranged from 5.90 to 10.0%. The calcium status of the soil is generally moderate which ranged from 4.36 to 6.22 me/l. Magnesium been the dominant cation ranged from 1.16 to2.26 me/l. The organic

matter of the soil is moderate as the values obtained ranged from 0.133 - 0.165%. The cation exchange capacity (CEC) of the soil ranged from 4.76 to 5.52me/l. Therefore, soil physical and chemical properties were the dominant factors influencing the extent of decomposition process and sustainability of agricultural productivity in the study area. It was recommended that Periodical test has to be conducted to ascertain any changes in values obtained and careful selection of crop and management alternatives is required if full yield potential is to be achieved.
Keywords: Soil Characteristics, Suitability & Agricultural production

Introduction

The soils ecological influence majorly in forest and natural environment cannot be overemphasized. Different soil characteristics including depth, consistency, temperature, nutrient contents, moisture content, permeability, porosity etc., can greatly influence the nature of vegetation that grows on them (Boyle and Powers, 2013). The physical, chemical and biological processes sustained by soil make it a dynamic zone consisting of inorganic (rocks) and organic particles (plant and animals remains), liquid (water and chemicals in solution) and gaseous substances (Isah*et al.*, 2014).

Soils are significantly affected by geologic and geomorphologic factors (water, wind, temperature change and gravity chemical interaction, topography, vegetation, living organism and pressure differences). However, living organisms such as vegetation also have an important role in a number of processes involved in soil formation including organic matter accumulation, profile mixing and biogeochemical nutrient cycling (Boul, 1990).

The maintenance of natural systems or soil fertility in tropical forest ecosystems is achieved by high and rapid circulation of nutrients through the fall and decomposition of litter which is a function of the season. The decomposed litter is also the basis of many food chains in tropical forests and is a principal source of energy for the biota of the forest floor and soil where the trophic chain of detritus predominates. Decomposition is a key process in the control of nutrient cycling and formation of soil organic matter (Boul, 1990).

The relationship between trees and soil is of importance since they are dependent on each other and on the environment as a whole (FAO, 2015). The support, nutrients and water needed by trees to grow is provided by soil while trees and other plants are important factors in the formation and enrichment of soil (FAO, 2015). The gathering of nutrients by different tree species as well as their potential to return these nutrients into the soils can cause variations in soil properties (Rawat, 2005).

Therefore, suitability of agricultural land and environment depend largely on consistent monitoring of soil quality. This study, however, examines the variations in the physicochemical properties of soil at three different depths in Malete area of Kwara State, Nigeria.

Description of the Study Area

The study area is located in Moro Local Government Area of Kwara State and lies within latitude 8°41’40”N to 8°43’20”N and longitudes 4°25’50”E to 4°30’0”E. It comprises of Malete, Kwara State University (KWASU) Campus and the adjoining communities covering an area of about (4,000 Hectares) of land as shown in Figure 1. Moro LGA was created in the year 1976. Moro is a Local Government Area in Kwara State, Nigeria. It has an area of 3,272 km^2 and a population of 108,792 at the 2006 census. The study area is more than 25 km north from Moro town, though a relatively virgin area, it is highly vulnerable to unplanned expansions due to its proximity to the state capital and recently the siting of Kwara State University (KWASU) campus.

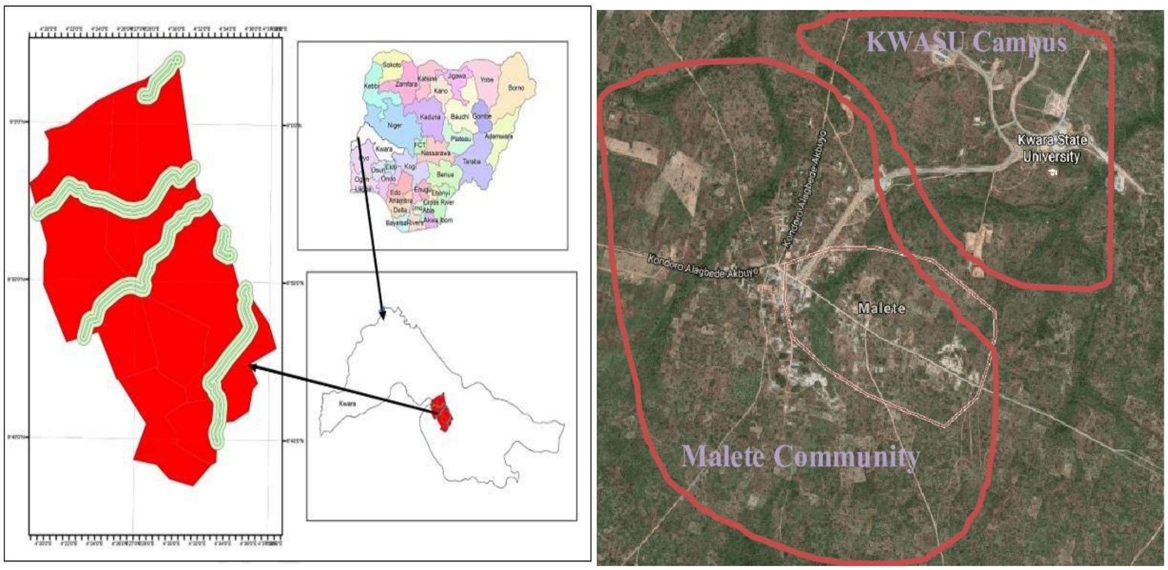

Figure 1: The map of the study area

Source: Atlas, 1981

Geological Information

Malete is located near Ilorin in Kwara State, Nigeria, and situated within the Nigerian Basement Complex which is dominated by crystalline rocks such as granite, gneiss and migmatite (Ajibade*et al.,* 2013). Additionally, the region may have sedimentary formations including sandstone, shale, limestone and clay which are part of the younger sedimentary basins in Nigeria such as the Sokoto Basin or the Bida Basin (Ajayi*et al.,* 2017). These geological formations contribute to the landscape and soil diversity of the area.

Soil Information

The soils in the Malete area are influenced by the underlying geology, climate and vegetation cover. Common soil types include ferruginous tropical soils characterized by their reddish-brown colour due to iron oxides, alluvial soils found in floodplain areas and lateritic soils which are weathered and leached soils rich in iron and aluminum oxides. The specific soil properties and distribution may vary across the landscape depending on factors such as topography and drainage patterns.

Vegetation and Relief

The vegetation in Malete reflects the ecological characteristics of the Guinea Savanna biome, which is typical of the region. This biome is characterized by a mix of grasslands and scattered trees, including species like Acacia, Isoberlinia and Combretum. Additionally, there may be patches of woodland and small forests, especially in areas with better moisture retention or protection from fire. Human activities such as agriculture have also shaped the vegetation landscape with crops like maize, cassava, yams and millet being common in the area (Ajayi*et al.*, 2017).

The topography of the Malete area in Kwara State, Nigeria varies featuring undulating hills, low-lying plains, river valleys and anthropogenic features like agricultural fields and settlements. Rivers have carved out valleys with distinct features while human activities have altered the landscape. Escarpments, depressions and basins also contribute to the diverse topography shaped by geological processes and human interactions. Her pre-Cambrian basement structure has a height variation of 200 to 364 meters in the east and 273 to 333 meters in the west. There are rainy and arid seasons and the temperature is humid tropical (Atlas, 1981).

The close of June marks the start of the rainy season which lasts until around October. With the arrival of the warm continental air mass known as harmattan, the community enters a dry season. Typically, this breeze is most prevalent from November to February (Olaniran, 2002). The year-round weather is consistently elevated. Between 1991 and 2000, the town's mean daily temperature ranged between 25°C and 29.5°C with the month of March having an average high of 30°C. Moro is located in the zone of the northern steppe. This region serves as a bridge. Her vegetation is distinguished by sporadic trees and bushes that are tall (savvanah). According to Oyegun's description of the flora in 1993, it is primarily made up of derived savannah located in the north central which is distinguished lowland rainforest plant cover. Malete is one of Kwara's local government areas with somewhat low population growth as observed from previous researches. Her population development rate is now faster than that of the previous years. Since 2009, Malete has experienced rapid demographic and geographic growth since the establishment of the KWASU Campus.

Soil Sampling Method

Soil samples were collected randomly from different locations in the study area at soil depths of 0-20 cm, 20-60 cm and 60-100cm using soil auger. The 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 collected using core cutters and sealed immediately on both edges with candle wax melted on the field to prevent loss of moisture.

Soil Chemical Analysis

The following methods were employed for the soil chemical analysis:

I. Soil pH was determined by pH meter in soil-water and soil-KCL filtrates.
II. CEC was determined titrimetrically following sequential leaching with ammonium acetate, 95% ethanol, 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 Walkley-Black wet digestion method.
V. Organic Matter (OM) in percentage was done by calculation: OM = OC x1.723.
VI. Calcium and Magnesium were determined using Atomic Absorption Spectrophotometer.

Physical Analysis

The following methods were employed for soil physical analysis:

I. The particle size analysis was done by hydrometer method employing sodium hexameta phosphate [Na $(HPO_4)_6$] calgon as the dispersing agent.

II. The available soil moisture content was determined using a digital moisture analyser.

III. Soil bulk density was determined by employed a core method.

IV. Particle density was used with bulk density to calculate soil porosity.

Results of Soil Physical Analysis

The physical parameters evaluated include soil texture, soil infiltration rates, soil temperature and available soil moisture content. 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. Soil particle size analysis revealed that soil in the study area is sandy loam using textural classification triangle chart. 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. Therefore, the soils appear moderately suitable for agricultural production but may be drought prone.

The 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 Shoenebergeret *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. The moisture contents for the sampling location points (Point 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 of the study area. 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. 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 the sampling location points (Point A, B, and C) around the study area are; 6.7ºC, 5.4ºC and 7.8ºC respectively and are moderately suitable for plant growth.

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					

Table 4: Average Particle Size Distribution of the Soil

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 5: Soil Infiltration Rate

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

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 indicate a decrease from 0 – 20cm to 20 – 60cm soil depth and subsequently tending towards neutral. In Figure 2, the minimum and maximum soil pH values are 5.30 and 6.87. According to the United State 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.

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

Source: Hert *et al.* (1999)

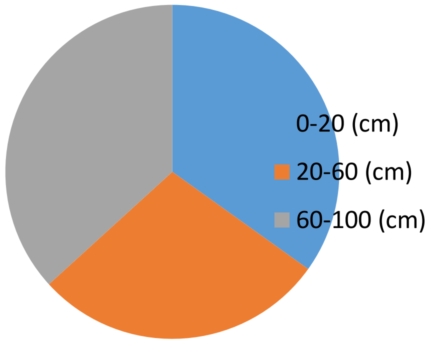

Figure 2: The soil available pH at three depths

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 for 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 surface depth (0 – 20cm) to the second depth (20-60cm) and sharply increased from second depth (20 – 60cm) to third depth (60 – 100cm) of the soil depths.

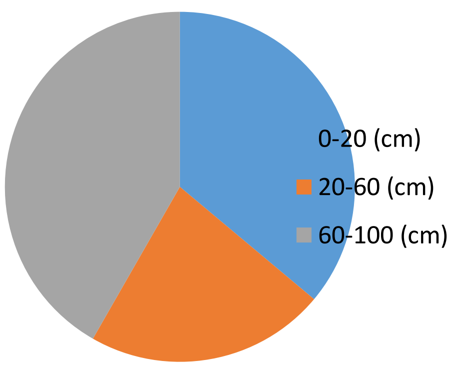

Figure 3: The soil organic carbon at three depths

Phosphorus is an essential macro-nutrient which is relatively needed by crops in large quantity for proper growth and development. The different level of the soil phosphorous on the soil at three depths is shown in Figure 4. Available phosphorous content of the soil is high and larger from 20.276 to 28.342mg/l. However, the soil will be good for crop that required much phosphorus.

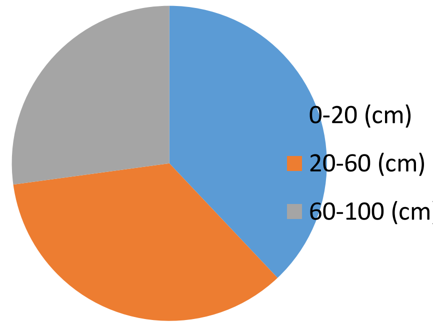

Figure 4: The soil phosphorous at three depths

Sodium, which determines the sodicity status of a soil is generally low and ranged from 0.156 to 0.653me/l. It is observed from Figure 5 that the level of sodium slightly decreased from 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 thus good for irrigation (Joseph *et al.*, 2014).

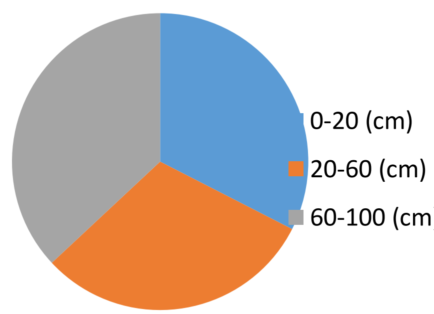

Figure 5: The soil sodium at three depths

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 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 to problem on the soil. The implication of a high ESP value on the soil is soil deterioration and unhealthy soil condition as stated by Marx *et al.* (1997). Excessive sodium level occurred in the study area was resulted from irrigation water with high sodium content.

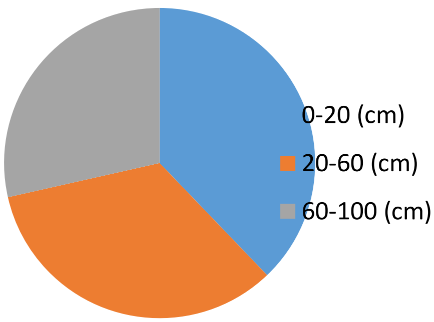

Figure 6: The soil ESP at three depths

The calcium in the soil of the study area is generally moderate and ranged from 4.36 – 6.22 me/l. Magnesium ranged from 1.16 – 2.26 me/l and been 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 as a result of leaching of the element during irrigation. This increase could be related to the increase in pH observed which is tending towards moderate to slightly acidic. It indicates that irrigation has led to the increase in the calcium level of the soil.

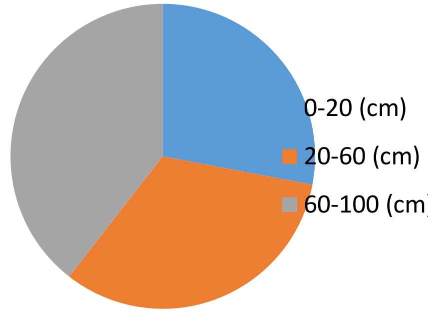

Figure 7: The soil calcium at three depths

In Figure 8, magnesium level slightly decreases from soil surface depth (0 – 20cm) to the second depth (20-60cm) and increased sharply from the second depth to the third depth (60 – 100cm). Magnesium is one of the secondary macronutrient required by plant. It 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 rapid rate of organic matter decomposition as a result of available moisture during irrigation.

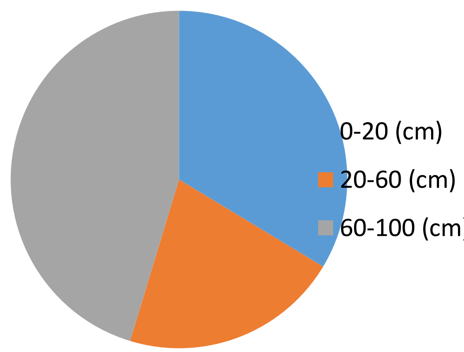

Figure 8: The soil magnesium at three depths

Figure 9 shows a decline in organic matter level of the soil at the soil surface depth. The soil is considered moderately suitable for irrigation due to moderate organic matter contents of the soil.

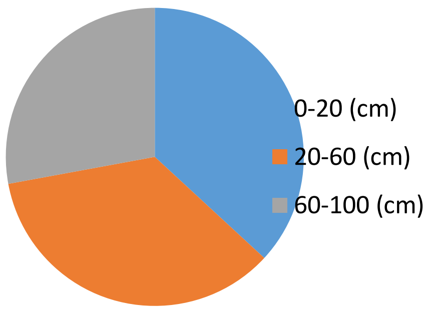

Figure 9: The soil organic matter at three depths

Cation exchange capacity (CEC) is a measure of soil capacity to retain and release element 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 increased level of CEC. Thus, soil currently falls within low to medium level as given by Edmeades*et al.* (1998).

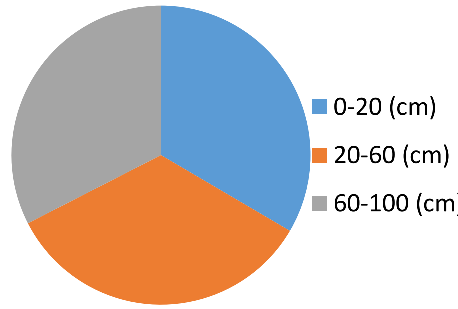

Figure 10: The soil CEC at three depths

Conclusion

The following conclusions were drawn from the study:

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

(v) Soil physical and chemical properties were the dominant factors influencing the extent of decomposition process.

(vi) Thus, agricultural land serves as protection for the soil as well as promoting the fertility and productivity of the soils to support a flourishing vegetation types in the area.

Recommendations

The following recommendations were drawn from conclusions:

(i) Periodical 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.

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