Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 19 Issue 1 Version 1.0 Year 2019
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Assessment of Spatial Variability of Physico Chemical Properties of Soil at Crop, Soil and Pest Management Research Farm, Futa

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Abstract- Soil is an important natural resource for growing plants and the suitability of soil for crop production is based on the quality of the soil's physical, chemical and biological properties. The objectives of the study were to determine the soil physical and chemical properties and characterize the spatial variability of soil physico-chemical properties across the study area. The study was conducted at Crop, Soil and Pest Management Research Farm, Futa. Soil samples were collected from six sampling depths between 0-60 cm at an interval of 10 cm at different 20 points across the field while coordinates of the soil sampling points were determined using Global Positioning System (GPS) procedures. The test for variance was carried out on physical properties of %sand, %silt, %clay, bulk density (g/cm^3), %porosity, %water holding capacity (WHC) and soil hydraulic conductivity and chemical properties on pH, organic matter content (%), total nitrogen (%), available phosphorus (ppm), calcium, magnesium, sodium and potassium (cmol/kg), and effective cation exchange capacity (cmol/kg).

Keywords: *spatial variability, soil physico-chemical property, GPS procedures, sampling point, land use management practices, fertility assessment.*

GJSFR-D Classification: *FOR Code: 050399, 070399*

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Assessment of Spatial Variability of Physico Chemical Properties of Soil at Crop, Soil and Pest Management Research Farm, Futa

Obafemi Olutola OLUBANJO [α] & Samuel Oluwamayowa AYOOLA [σ]

Abstract- Soil is an important natural resource for growing plants and the suitability of soil for crop production is based on the quality of the soil's physical, chemical and biological properties. The objectives of the study were to determine the soil physical and chemical properties and characterize the spatial variability of soil physico-chemical properties across the study area. The study was conducted at Crop, Soil and Pest Management Research Farm, Futa. Soil samples were collected from six sampling depths between 0-60 cm at an interval of 10 cm at different 20 points across the field while coordinates of the soil sampling points were determined using Global Positioning System (GPS) procedures. The test for variance was carried out on physical properties of %sand, %silt, %clay, bulk density (g/cm^3), %porosity, %water holding capacity (WHC) and soil hydraulic conductivity and chemical properties on pH, organic matter content (%), total nitrogen (%), available phosphorus (ppm), calcium, magnesium, sodium and potassium (cmol/kg), and effective cation exchange capacity (cmol/kg). The laboratory analysis (soil textural analysis) revealed that the soil type at the site was were predominantly Sandy Clay Loam. Gravimetric soil moisture content and the water holding capacity (WHC) in all the 20 sampling spots at the topsoil has a mean value of 9.13% ± 1.90 and 52.43%±2.45 respectively. The minimum and maximum hydraulic conductivity (K) value at the distribution shows a moderately skewed distribution of the K data and the distribution is positively skewed. The mean pH value of the soil in the study site was found to be slightly acidic and the soils were low in soil OM. The CEC, Mg^{2+}, OC, TEB and TN indicated significant difference for soil chemical properties. The physical properties and chemical properties as at the time of the study were found to be optimal for crop production, fertility assessment and land use management practices for crop productions and drip irrigation is suitable for the study area.

Keywords: spatial variability, soil physico-chemical property, GPS procedures, sampling point, land use management practices, fertility assessment.

I. Introduction

Soil is an important natural resource for growing plants. The suitability of soil for crop production is based on the quality of the soil's physical, chemical and biological properties. Soil therefore, is a dynamic natural body having properties derived from the combined effects of climate and biotic activities, as modified by topography, acting on parent materials over time. (De Gomez, 2015). One of the naturally occurring processes that affect soil properties and subsequent crop production is the pattern of water movement along the slope. The geometry of slope such as slope angle, length and curvature influence runoff, drainage, and soil erosion causing a significant difference in soil physico-chemical properties (Musa and Gisilanbe, 2017).

There are several human activities that can alter the soil properties of ecosystems such as, agricultural practices, urbanization and mining. Due to the nature (aridity) and climate of Nigeria the most common practice that has an adverse effect on the soil or ecosystems on the larger scale is mining (Linus, 2010; Burke, 2014)

Variability in soil properties is a direct result of the five soil forming factors: climate, organisms, relief, parent materials and time. Of the five soil forming factors, relief (topography) can be the most readily assessed factor as the changes in field topography influence the distribution of soil properties and crop productivity. (Mzuku *et al*., 2005: Akbas, 2014).

A better knowledge of the spatial variability of soil properties is important for refining agricultural management practices and for improving sustainable land use as reported by Akbas (2014); Omotade and Alatise (2017). Also, understanding the role of several soil properties together, and their interactions, may help to explain the cause of variation in crop productivity as defined by the management practices (Rahal, 2015). Spatial variability is primarily attributable to the differences in the soil physical and chemical properties while temporal variability may be as a result of farming systems or moisture content differences (Koech *et al*., 2010; Omotade and Alatise, 2017). Temporal variability is as a result of infiltration variability that causes non uniformity in soil moisture content. Water is essential to plants and to complement natural sources, irrigation is introduced to satisfy plant moisture requirements. Irrigation can ensure adequate and reliable supply of water which increases yields of most crops by 100% to 400%. For any given irrigation interval, optimal irrigation required less (48-63%) water than full irrigation. This also reduced both the deep percolation and runoff losses and caused a 31-43% increase in the application efficiency (Omotade and Alatise, 2017).

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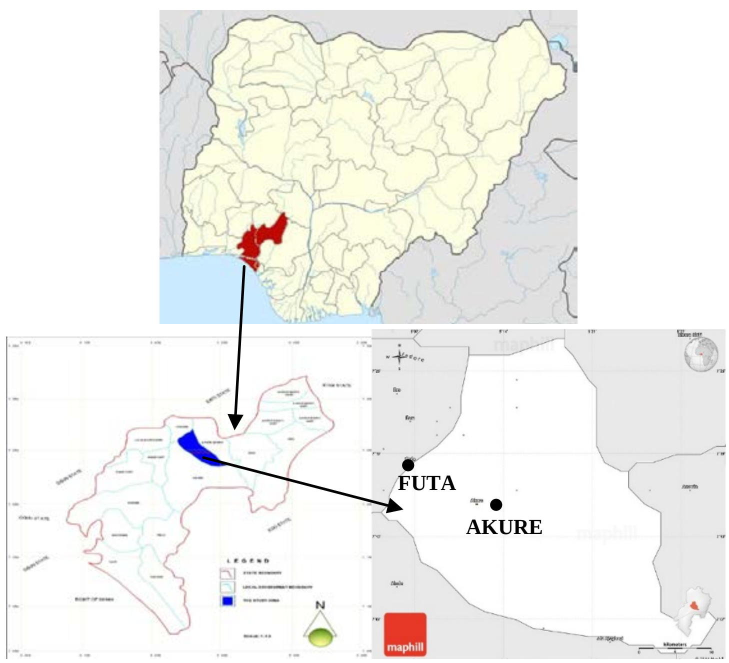
Soil spatial variability is an important determinant of efficiency of farm inputs and yield, (Rahal, 2015) as well as crop management and design and effectiveness of field research trials .These variations differed among soil properties, and may reflect the impacts of plant, soil fauna, precipitation, and management practices adopted in the area (Rahal, 2015). Consequently, soils can exhibit marked spatial variability at the macro-scale and micro-scale. High variability of soil properties might be related to variability of properties of flood sediments, and controlled by primarily the depositional environment where high energy systems deposit materials with high spatial variability (Rahal, 2015; Omotade and Alatise, 2017). These processes and causes create pattern of nested variability or heterogeneity, this means that, soil properties may display spatial/or temporal patterns only over certain distances and not others (Douaik, 2011; Rahal, 2015).

The characterization of the spatial variability of soil attributes is essential to achieve a better understanding of complex relations between soil properties and environmental factors (Goovaerts, 1998: Taiwo *et al*., 2016). Also, useful estimates of attributes at unsampled locations, leading to better recommendations for the application of water, plant nutrients, fertilizers or pesticides can be achieved from the modelling of spatial dependence between soil data (Goovaerts, 1998). The objectives of the study was to determine the soil physical and chemical properties and characterize the spatial variability of soil physico-chemical properties, determine the type of irrigation system and crop that is suitable for the study area.

II. Materials and Methods

a) Study Area

This study was conducted at the Crop, Soil and Pest Management Research Farm Land, Federal University of Technology Akure Ondo State, Nigeria. Akure is located on the latitude 7°13'N and longitude 5°13'E within the humid region of Nigeria and lies in the rain forest zone with a mean annual rainfall between 1300-1600mm and an average temperature of 27°C. The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. The study was carried within a total marked size of 2476m^2 (Omotade and Alatise, 2017).



Source: *Googlemap, 2018*

Figure 1: Map of Nigeria Showing Ondo State, Akure and FUTA

b) Soil Sampling Techniques and Preparation

i. *Soil sampling techniques*

Random Soil samples was collected within the area within six sampling depths 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm and 50-60 cm of the soil using a soil auger at 20 different points covering the study site. A total of 20 sub-samples were taken at the depth of 0-10 cm using a garden shovel, away from the nearby plants in the open area. Plants affect physical and chemical soil properties through the alteration of infiltration and runoff (Esler and Cowling, 1993; Sanjib *et al*., 2016), therefore samples were taken away from them. These soil samples were obtained to determine the soil moisture content at different depths and collectively added together to determine the spatial variability of all other properties at different points within the study area i.e. (Point A to T= soil from depths (0-10 cm) + (10-20 cm) + (20-30 cm) (30-40 cm) + (40-50 cm) + (50-60 cm) accordingly). The sampling points were located on the site using Global Positioning

System (GPS) equipment. The highest elevation is 381m while lowest level is 365 m above sea level as shown in Figure 2 with spatial variability of soil attributes in different landscape positions which was determined using geo-statistics techniques (Omotade and Alatise, 2017).

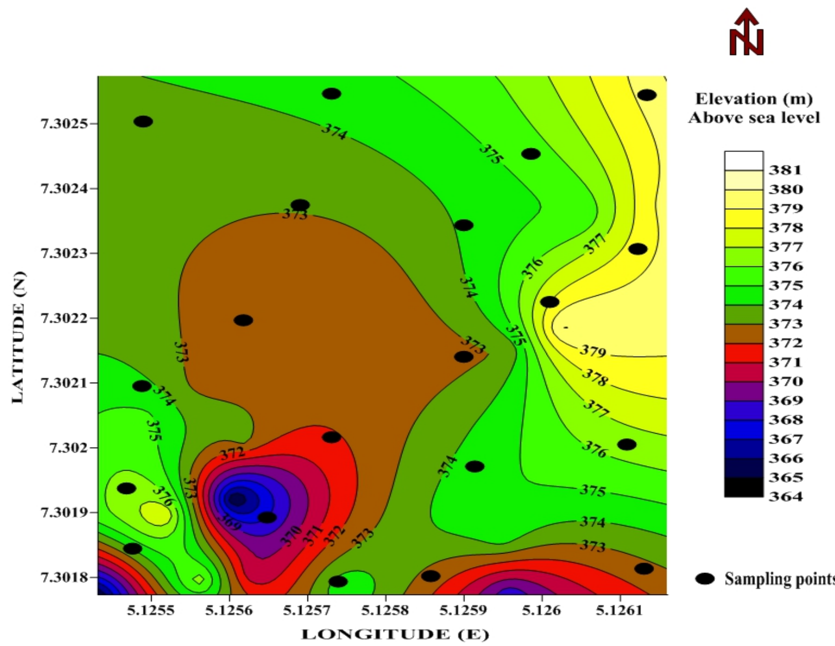


Figure 2: Map showing the elevation of the study area above the sea level

c) Soil Physical Properties

The particle- size distribution (soil texture) was determined by Bouyoucos hydrometer method (Gee and Bouder, 1986; Omotade and Alatise, 2017). The soil bulk density was determined using cylindrical metal core sampler method (Musa and Gisilanbe, 2016) by dividing the weight (W) of dry soil by the internal core volume (v) of the core sampler. Thedefaultvalueof2.65 Mg/m^3 is used as a rule of thumb based on the average bulk density of rock with no pore space to determine the total porosity (PD) (Fasinmirin and Olorunfemi, 2013; Taiwo *et al*., 2016). The total porosity in m^3m^{-3}, was estimated using the ratio between the BD and PD through the following equation (Fasinmirin and Olorunfemi, 2013). The soil moisture content was determined using gravimetric method (Omotade and Alatise, 2017). The Values of soil water holding capacity (SWSC) at the 0.00-0.60 m depth, expressed in percentage, were calculated by the expression (Taiwo *et al*., 2016).

d) Soil chemical properties

The pH of soil was measured on all the collected soil samples (120 soil samples) on saturated paste using digital electronic pH meter (Sanjib *et al*., 2017). The Walkley-Black method was used to determine the percentage organic matter in all samples of soil and post-mining waste materials (Sanjib, 2016; Omotade and Alatise, 2017). A modified Kjeldahl method was used to determine total nitrogen of soil samples (Sanjib, 2016; Omotade and Alatise, 2017). The content of Extractable macronutrients (Mg^{2+}, P and Ca^{2+}) and (K^+ and Na^+) in the 120 soil samples collected during field work was extracted at the analytical laboratory using neutral normal ammonia acetate and flame photometry (Sanjib *et al*., 2016). The available Phosphorus was determined by extraction method using spectrometer and Bray's P-1 reagent (Musa and Gisilanbe, 2017).

The obtained data was analysed using statistical analysis such as descriptive statistics; Minimum (Min), Maximum (Max), Mean, Standard deviation (SD), Coefficient of variance (CV) and Skewness using Microsoft Excel 16.00 (Microsoft Inc., USA) software package for windows (Omotade and Alatise, 2017) The relationship between the studied Soil properties were established using Pearson's correlation coefficient analysis. Significant difference were observed at $P > 0.05$ (Sanjib *et al*., 2016)

All data corresponding to each grid point location were interpolated spatially using global positioning system (GPS) and selected data will be interpolated using SURFER software. The point XYZ data survey of the prescribed sample grids at the agricultural farm will be analysed for land scape positioning, according to the landform classification developed by Pennock *et al*. (1994).

III. Results and Discssion

a) Soil Physical Properties

i. *Soil texture*

The soil textural analysis was performed on the soil samples taken from the study area for depth 0-30 cm and the relationships were presented in the Figure 3. The laboratory analysis (soil textural analysis) revealed that the soil type at the site was were predominantly Sandy Clay Loam according to USDA soil textural classification (Soil Survey Staff, 1999). Sandy Clay Loam usually facilitates water infiltrability and nutrients retainability (Shukla and Lal, 2002; Omotade and Alatise, 2017). The descriptive statistics of particle size distribution of the site indicates that the soils generally have an average sand content of 45.80% ± 5.60, 46.50% ± 4.51, 46.90% ± 4.75 for depth 10 cm, 20 cm and 30 cm respectively as presented in Table 1.

Table 1: Descriptive statistics of particle size distribution of the experimental site

Variables/statistics	%Sand			%clay			%silt		
Depths, cm	10	20	30	10	20	30	10	20	30
Mean	45.80	46.50	46.90	37.80	36.10	35.80	16.40	17.40	17.30
StDev	5.60	4.51	4.75	6.56	5.93	5.35	2.11	2.26	1.49
CV	31.37	20.33	22.52	42.99	35.15	28.67	4.46	5.09	2.22
Kurtosis	-0.86	1.44	-0.45	-0.62	0.26	-0.40	-0.48	-1.46	-0.76
Skewness	-0.67	-1.51	-0.25	0.98	1.15	0.14	0.75	-0.07	0.70
Range	16.00	16.00	18.00	18.00	18.00	20.00	6.00	6.00	4.00
Min	36.80	36.80	36.80	31.20	31.20	27.20	14.00	14.00	16.00
Max	52.80	52.80	54.80	49.20	49.20	47.20	20.00	20.00	20.00
Count	20	20	20	20	20	20	20	20	20

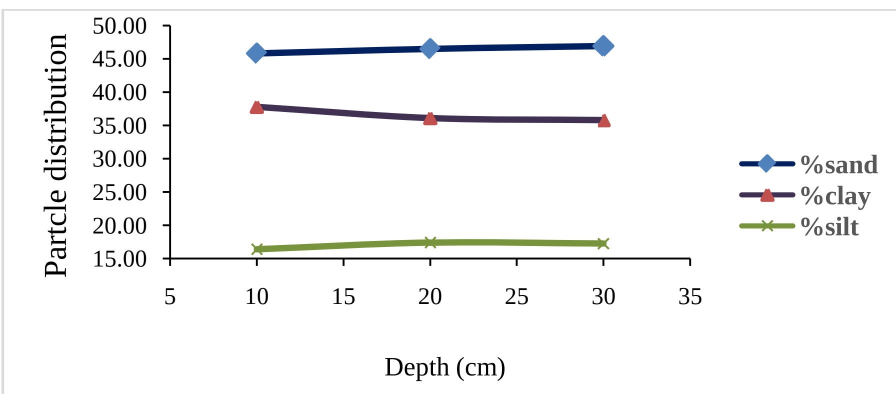


Figure 3: The textural classification of soil

ii. *Bulk density (BD) and Total porosity (TP) of experimental field*

Bulk density (BD) increased significantly with depth from about 1.28 Mg/ m^3 to 1.59 Mg/ m^3 in the top 10 cm depth to 1.61 Mg/m^3 in the 60 cm depth ($p \leq 0.001$) (Table2). As expected, mean Total Porosity, TP (0.46>0.45>0.44>0.43 m^3/ m^3) also significantly decreased with soil depth ($p \leq 0.001$) (Table 2). The general trend of increase in BD observed in the soil layers is in conformation with Vereecken *et al.* (1989), Adeyemo and Agele (2010) and Fasiminrin and Olorunfemi (2012). The increase down the soil profile is probably due to changes in soil texture, gravel content, and structure (Landsberg *et al*., 2003) but also because of biological activity on surface soils with high organic matter content which decreases across the soil profile (Fasinmirin and Olorunfemi, 2013 and Taiwo *et al.*, 2016.). This is also expected because of the overburden weight of soil above the depth of measurement (Taiwo *et al*., 2016). Total porosity as expected showed inverse relationship to the bulk density of the experimental site (Figure 2). This observation agrees with the works of Vogelmann *et al.*, (2010) Olorunfemi and Fasinmirin, 2012 and Taiwo *et al*., 2016). Meanwhile, values for the BD at the experimental field are similar to those reported by, Fasinmirin and Olorunfemi (2013) and Taiwo *et al.*, (2016).

Table 2: Descriptive statistics of bulk density (BD), total porosity (PT),Soil Water Holding Capacity (SHWC) and Soil Hydraulic Conductivity (K) of the experimental field

Variables/statistics	BD, g/cm^3			TP, m^3/m^3			SHWC (%)			K(cm/hr)		
Depths, cm	*30*	*20*	*10*	*30*	*20*	*10*	*30*	*20*	*10*	*30*	*20*	*10*
Mean	1.468	1.425	1.425	44.614	46.219	46.219	52.734	53.745	52.430	0.00888	0.00925	0.00917
Median	1.490	1.410	1.435	43.773	46.791	45.838	53.097	53.606	52.577	0.00015	0.00014	0.00013
StDev	0.083	0.052	0.106	3.130	1.967	4.012	2.587	2.072	2.445	0.00875	0.00929	0.00916
CV	0.007	0.003	0.011	9.797	3.868	16.094	6.693	4.293	5.976	0.00069	0.00062	0.00058
Kurtosis	-1.155	-0.423	-1.395	-1.155	-0.423	-1.395	-0.395	-1.212	-0.892	0.65318	-0.29732	-0.34450
Skewness	-0.427	0.532	0.155	0.427	-0.532	-0.155	-0.806	0.182	-0.173	0.00236	0.00216	0.00210
Min	1.322	1.347	1.280	40.596	41.867	39.961	47.884	50.689	48.432	0.00795	0.00801	0.00808
Max	1.574	1.541	1.591	50.126	49.173	51.714	55.841	57.076	56.116	0.01031	0.01018	0.01018
Sum	29.354	28.504	28.504	892.290	924.374	924.374	1054.687	1074.910	1048.599	0.17753	0.18492	0.18339
Count	20	20	20	20	20	20	20	20	20	20	20	20

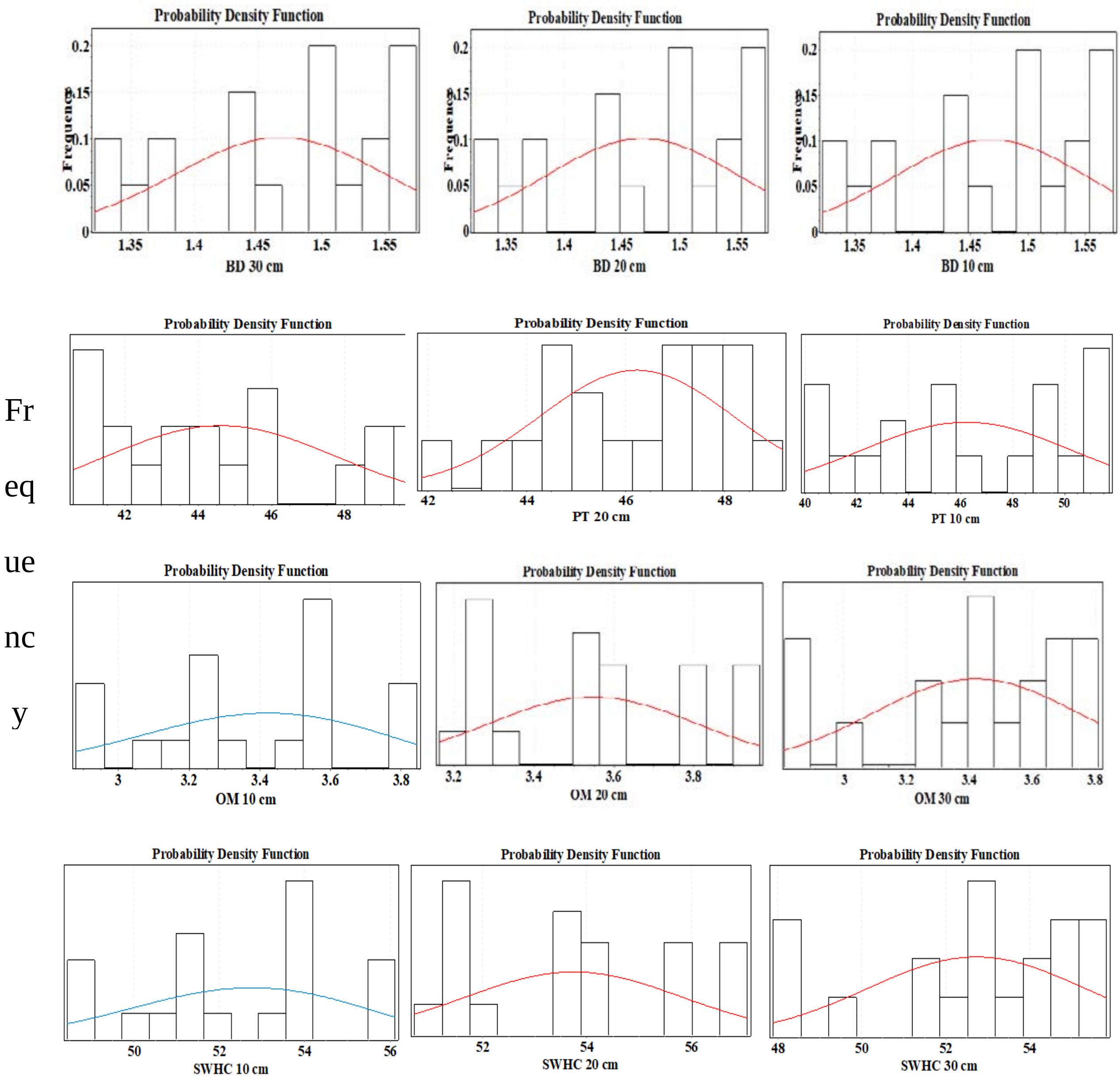


Figure 4: Histogram with normal curve of bulk density (g/cm^3), total porosity (m^3/m^3), soil water holding capacity (%) and soil organic matter (%) of the experimental field at 10, 20 and 30 cm depths respectively

iii. *Soil Moisture Content, Soil Water Holding Capacity (SWHC) and Soil Hydraulic Conductivity (K)*

The knowledge of these soil hydraulic properties and the soil water storage capacity processes leads to better predictions of both agricultural and environment impact. Soil hydraulic properties also define the relationship between soil moisture, hydraulic head and hydraulic conductivity, thus controlling how water moves through the soil. (Taiwo *et al*., 2016)

Gravimetric soil moisture content ranged from 5.33% to 14.52% in all the 20 sampling spots at the topsoil with a mean value of 9.13% ± 1.90 and coefficient of variation of 3.6. The water holding capacity (WHC) ranged from 48.43% to 56.12% for all the top soil layer in the 20 sampling locations with an average value of 52.43%, standard deviation of 2.45 and coefficient of variation of 5.95. The minimum and maximum hydraulic conductivity values were 10.30 mm h^{-1} and 8.90 mmh^{-1} with a mean value of 8.9 mmh^{-1}. The coefficient of variation was 0.49 and the standard deviation was 0.7. Skewness coefficient of 0.65 for the K data at the distribution shows a moderately skewed distribution of the K data and the distribution is positively skewed. Further use of Shapiro – wilk statistics and frequency distribution curves (Figure 4) shows that there is enough evidence to suggest that the data do not follow a normal distribution at 0.05 significant levels. (Elnagger *et al*., 2013; Taiwo *et al*., 2016).

b) Soil Chemical Properties

i. Soil pH

Table 3a and 3b shows the result of the descriptive statistics of soil chemical properties present for the upper, middle and the lower depth of the soil at the study site. Figure 5 shows the spatial distribution of hydrogen ion concentration across the study for the upper, middle and lower depth of the study area. The mean pH value of the soil in the study site was found to be 5.65, 5.64 and 5.72 for depth 10 cm, 20 cm and 30 cm respectively which is found to be slightly acidic. Optimum pH for most agricultural crops falls between 6.0 and 7.0 because nutrients are more available at pH about 6.5(Ajayi *et al*., 2010; Omotade and Alatise, 2017). Therefore makes the study area fairly suitable for the cultivation of agricultural crops as the pH across the site falls around the optimum value.

Table 3a: The descriptive statistics of soil chemical properties at the study Area at 10, 20 and 30 cm depths respectively

Variables/statistics	pH			P (mg/kg)			N (cmol/kg)			K (cmol/kg)		
Depths, cm	10	20	30	10	20	30	10	20	30	10	20	30
Mean	5.65	5.64	5.72	3.90	3.53	2.97	0.34	0.30	0.31	0.58	0.49	0.43
Median	5.60	5.75	5.76	4.08	2.65	2.75	0.33	0.31	0.30	0.59	0.42	0.42
StDev	0.21	0.26	127.07	1.74	1.65	0.99	0.04	0.05	0.04	0.12	0.19	0.16
CV	0.04	0.07	16147.07	3.04	2.72	0.97	0.00	0.00	0.00	0.01	0.04	0.03
Kurtosis	1.27	-0.49	20.00	-1.13	-1.27	5.68	-1.04	0.19	-1.57	0.81	1.20	-0.27
Skewness	-0.43	-0.64	4.47	0.16	0.68	2.18	0.20	-0.68	0.17	-0.80	1.42	0.77
Range	0.86	0.92	568.73	4.99	4.86	4.28	0.13	0.18	0.10	0.46	0.68	0.54
Min	5.10	5.10	5.27	1.71	1.71	1.92	0.27	0.20	0.26	0.26	0.22	0.22
Max	5.96	6.02	574.00	6.70	6.57	6.20	0.40	0.38	0.36	0.72	0.90	0.76
Count	20	20	20	20	20	20	20	20	20	20	20	20

Table 3b: The descriptive statistics of soil chemical properties at the study Area at 10, 20 and 30 cm depths respectively

Variables/statistics	CEC (cmol/kg)			Na (cmol/kg)			Ca (cmol/kg)			Mg (cmol/kg)		
Depths, cm	10	20	30	10	20	30	10	20	30	10	20	30
Mean	9.82	9.08	8.79	0.64	0.31	0.27	2.52	2.60	2.54	1.17	1.19	1.20
Median	9.93	8.73	8.43	0.42	0.30	0.23	2.20	2.55	2.40	1.10	1.20	1.20
StDev	1.22	1.70	1.98	0.52	0.07	0.13	0.51	0.21	0.39	0.36	0.09	0.22
CV	1.49	2.89	3.92	0.27	0.01	0.02	0.26	0.05	0.15	0.13	0.01	0.05
Kurtosis	0.05	0.06	-0.16	2.21	0.10	0.23	0.05	-0.36	0.11	1.67	0.66	0.17
Skewness	-0.26	1.12	1.04	1.88	0.91	1.14	1.25	0.87	0.67	1.70	0.21	0.61
Range	5.08	5.14	5.60	1.59	0.26	0.43	1.50	0.60	1.30	1.10	0.40	0.80
Min	7.10	7.06	6.85	0.23	0.20	0.13	2.10	2.40	2.00	0.90	1.00	0.90
Max	12.18	12.20	12.45	1.82	0.46	0.56	3.60	3.00	3.30	2.00	1.40	1.70
Count	20	20	20	20	20	20	20	20	20	20	20	20

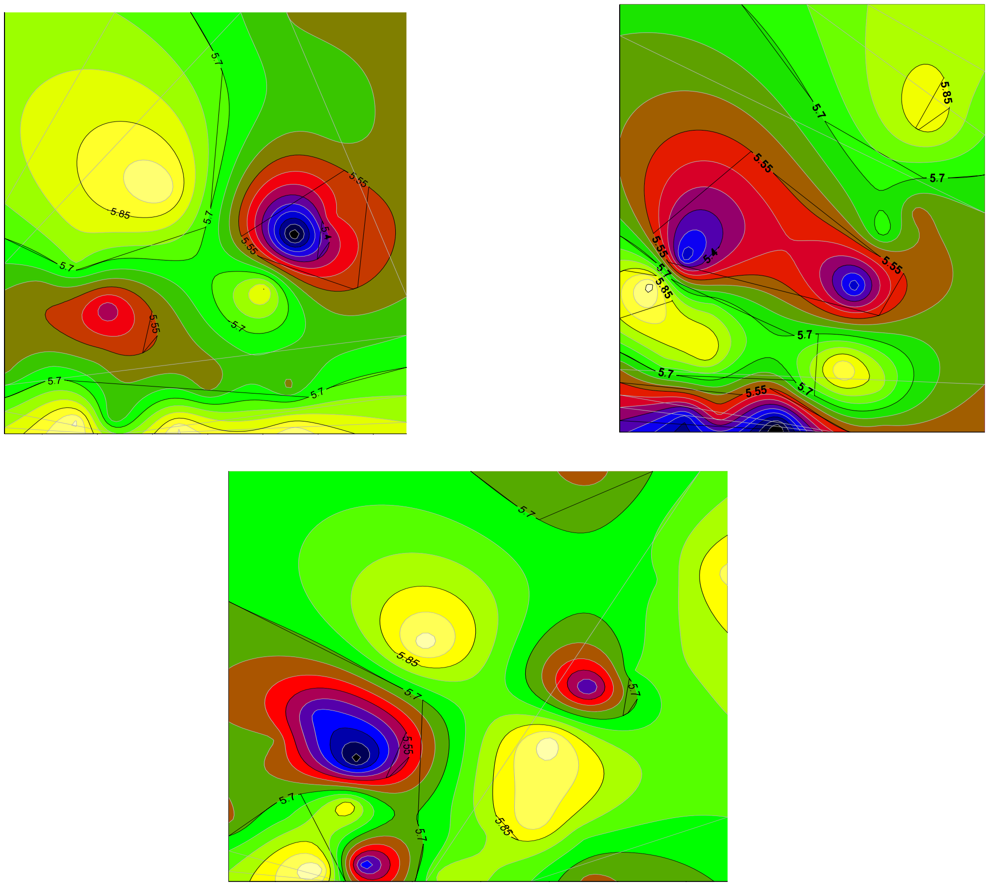


Figure 5: Spatial distribution map of hydrogen ion concentration at the study area

ii. *Cations exchange capacity (CEC)*

The CEC's across the study area spatially varied within the range of 7.01 to 12.45cmol/kg, with the average value of 9.82±1.22 and CV of 1.49 (Figure 6). The values of the soil CEC at the study area fell within the medium range based on this classification since most their values fell below the standard value of 12cmol/kg (Adepetu *et al*., 1979: Elnagger *et al*., 2013). The presence of these CEC values is influenced by high clay content, organic matter and the soil pH (Noma *et al*., 2005:Taiwo *et al*., 2016).

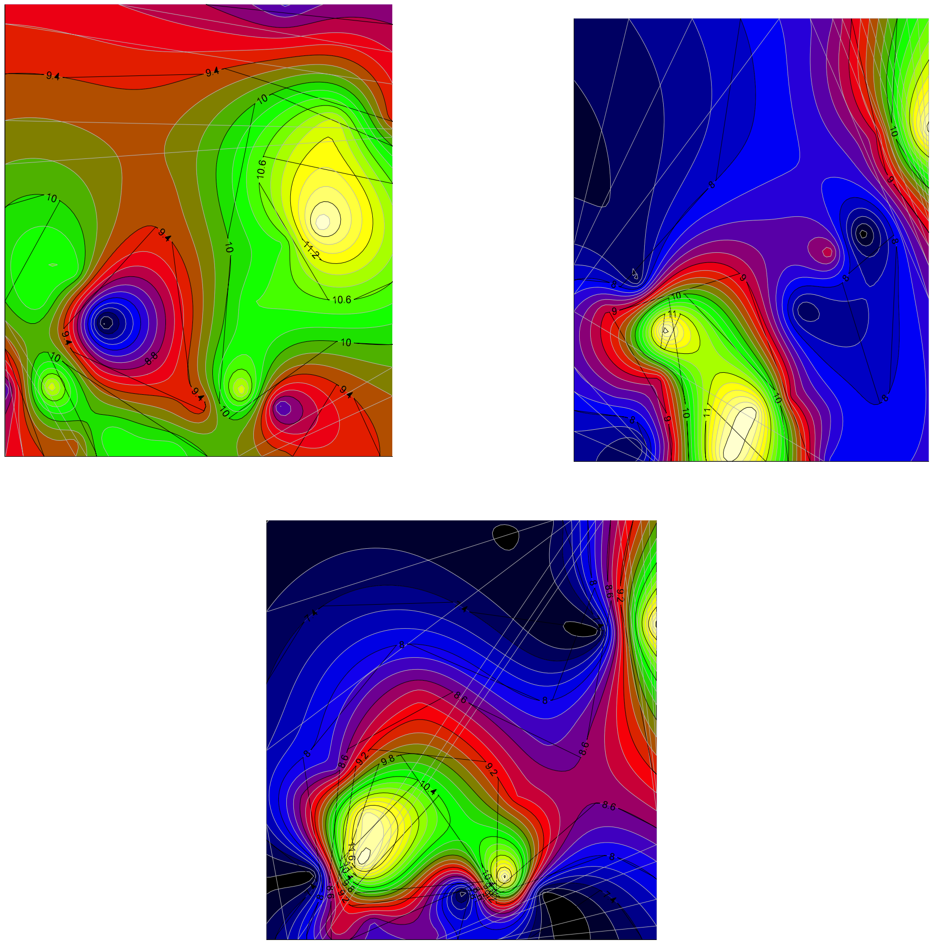


Figure 6: Spatial distribution map of Cations exchange capacity (CEC) at the study area

iii. *Soil organic matter content (OM)*

Organic matter (OM) contents can be used as physical or chemical soil properties. They are used as physical soil properties, when we refer to them as soil components and their effect on physical properties. Also, they are used as chemical soil properties due to their great effects on chemical properties. In this work they were studied under chemical properties. Soils in Crop Soil and Pest management research farm were poor in their organic matter content. The Organic matter (OM) content found in the study area varied from low (2.88%) to high (3.97%).

The spatial distribution of OM in the CSP research farm is illustrated in Fig 4.4. About 60% of soils in the research farm had average values less than 2.9%, about 40% had values between 3.4 and 3.9%. The lower values were generally associated with coarse-textured soils, whereas the higher values were linked with medium to fine varied from 2.85 to 3.39% with an average of 3.54±0.26% with CV of 0.07 (Figure 7).

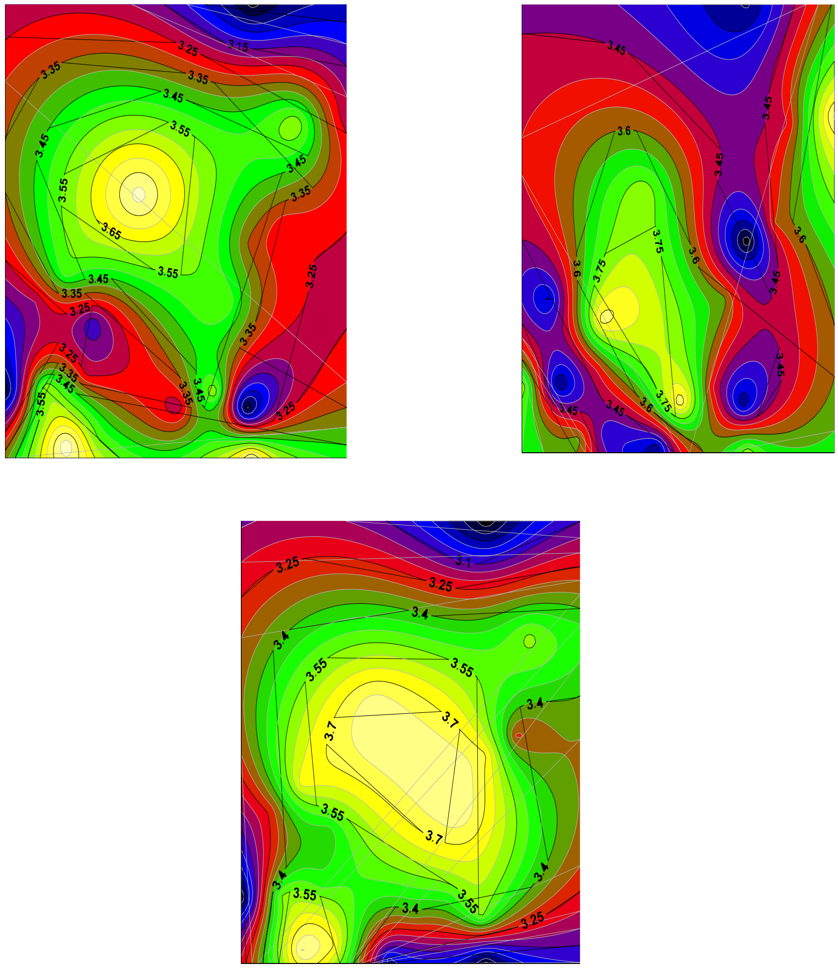


Figure 7: Spatial distribution map of soil organic matter content at the study area

iv. *Soil potassium content*

The spatial map on Figure 8 showed the distribution of potassium on the field at both 10 cm, 20cm and 30 cm deep. High variability of potassium values distribution between the range 0.64 mg/kg to 0.72 mg/kg were observed at the middle south and north eastern region of the field at depth 10 cm, at the core west at middle layer with range values of 0.75 mg/kg to 0.9 mg/kg. Moderate potassium values distribution between the range of 0.4 mg/kg to 0.56 mg/kg stretched from the North West to the south eastern part of the field at depth 10 cm and were observed at the western part of the field at 20 cm depth. Soils with high clay content and organic material can hold or have good reserves of potassium. Low potassium values between the ranges of 0.28 mg/kg to 0.35 mg/kg dominated eastern part of the field at every depth. Deficiency of potassium in soil is as a result of higher rainfall because potassium is a mobile nutrient that leaches in sandy soil. (Fasinmirin and Olorunfemi, 2013)

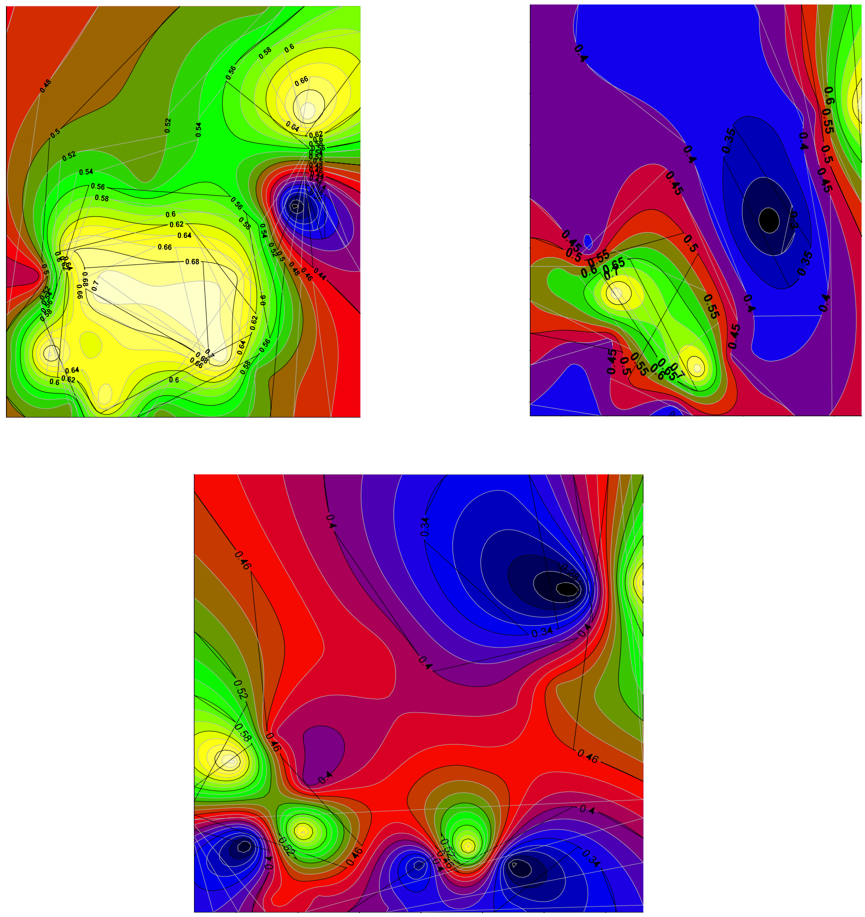


Figure 8: Spatial distribution map of soil potassium at the study area

v. *Spatial variability of the soil phosphorus*

In Figure 9, there is high phosphorus content at the eastern part stretching towards the western part and at the south eastern end but with a smaller distribution in the western southern part between the range of 5.4 mg/kg and 6.6 mg/kg. The phosphorus is moderate at the south western region between the range of 3.8 mg/kg and 5.06 mg/kg. Phosphorus is low at the north western region stretching to the south western corner between the range of 1.7 mg/kg and 3.4 mg/kg. Spatial distribution of soil type and slope causes phosphorus loss due to erosion and run off which was estimated in some part of the field.

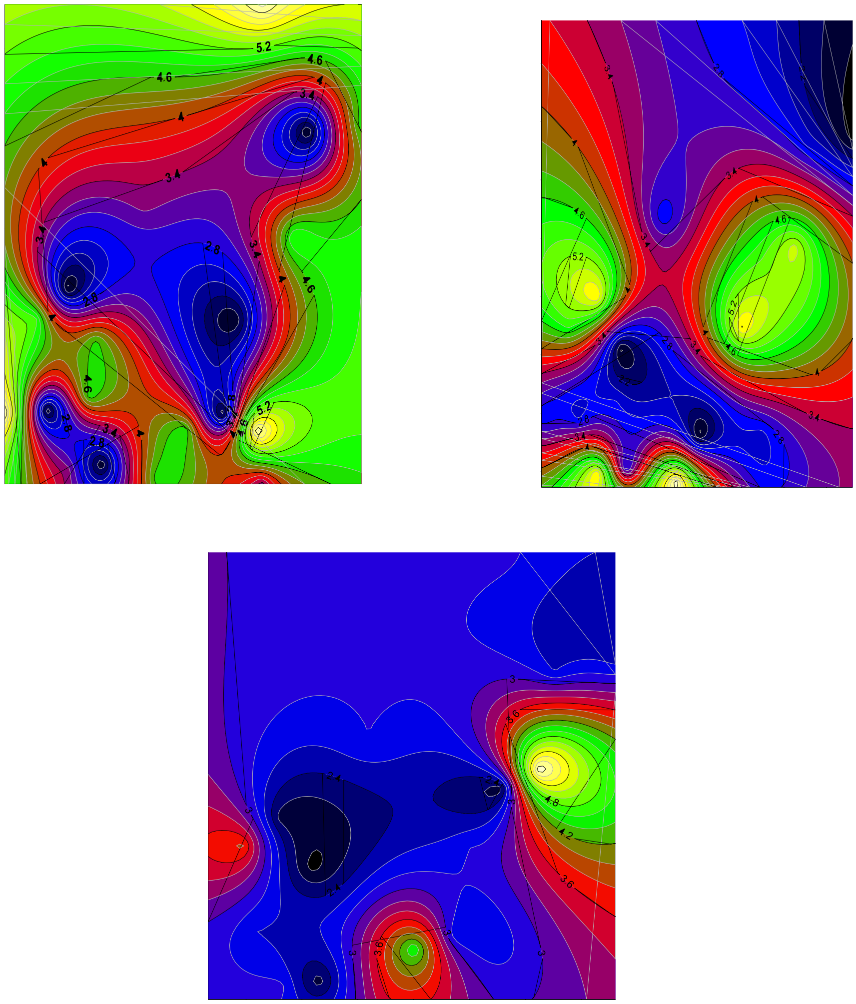


Figure 9: Spatial distribution map of soil phosphorus at the study area

vi. *Spatial variability of the soil nitrogen*

Figure 10 showed the spatial pattern of nitrogen in the soil. High nitrogen values between the ranges of 0.37% to 0.4% were observed at the southern region of the field in a small proportion. Moderate nitrogen values between the ranges 0.32% to 0.36%stretched from the North West, eastern and to the south eastern region of the field. Low nitrogen values between the ranges of 0.27% to 0.30% stretched from the western region towards the south eastern region at a larger distribution. According to Isirimah and Igwe (2003) in Omotade and Alatise (2017) low content of nitrogen in the soil is as a result of leaching caused by erosion and low organic matter.

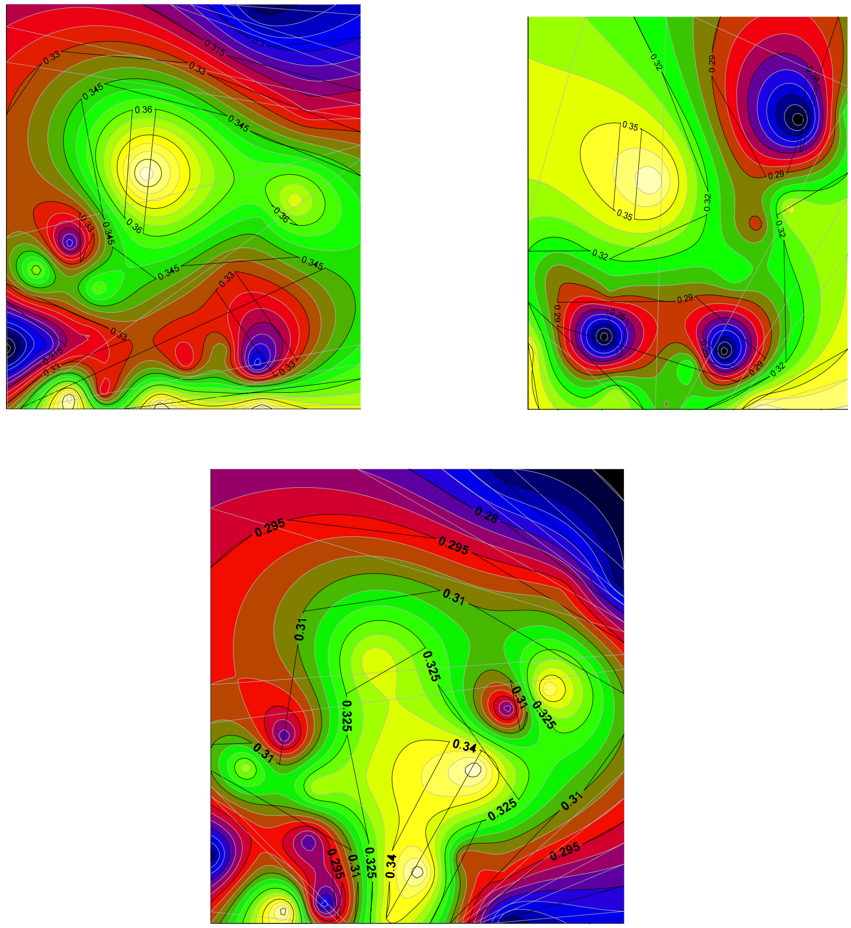


Figure 10: Spatial distribution map of soil nitrogen at the study area

The deduced values of the Phosphorus (P), Nitrogen (N), and Potassium (K). The differences between the values of K at all different points in the soil were not significant compared N, Ca, P and Mg as wide variability occurred in their values. Also the average content of Ca was relatively far higher than that of Mg with values ranging from 2.10 to 3.90 cmol/kg. It varied from 0.14 to 1.46% with an average of 0.74%. The distributions of the average values of other trace nutrients like Calcium, Sodium and Magnesium are respectively presented in Figure 11 to13for the upper, middle and lower depth of the study area.

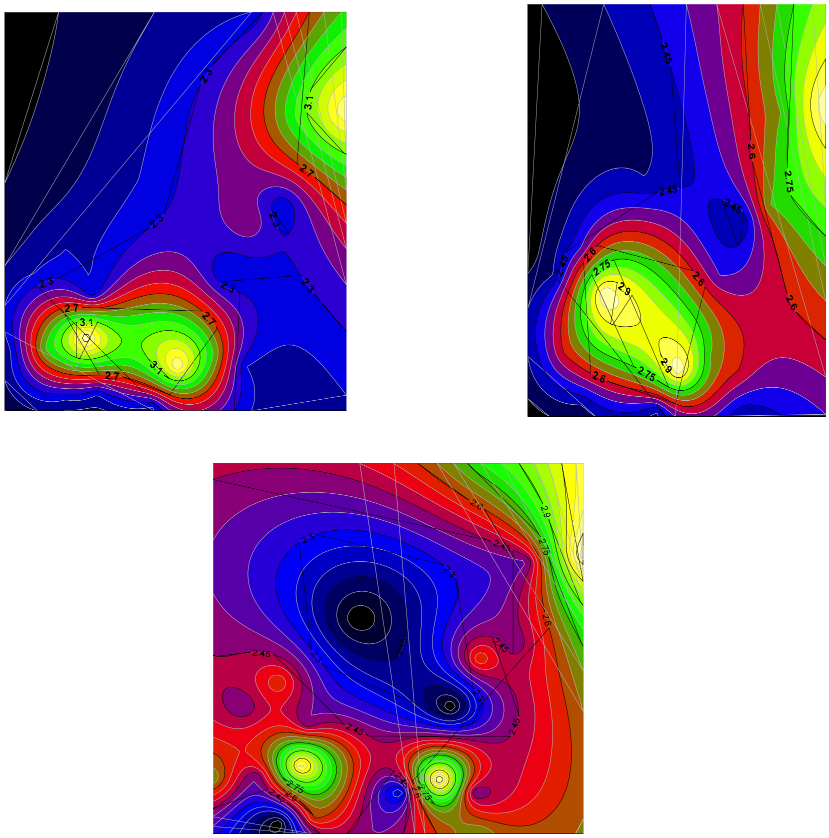


Figure 11: Spatial distribution map of soil calcium at the study area

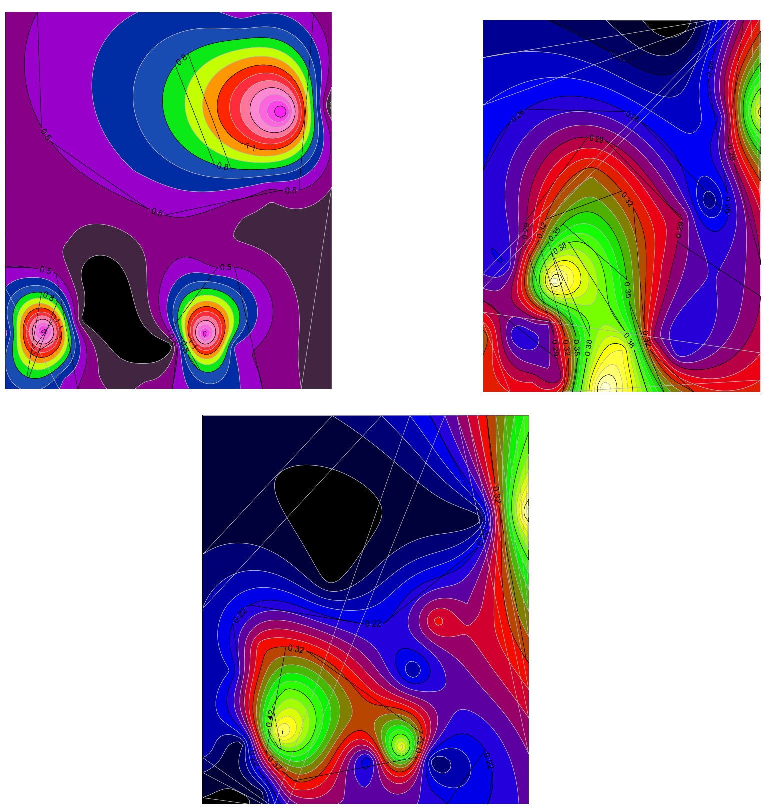


Figure 12: Spatial distribution map of soil sodium at the study area

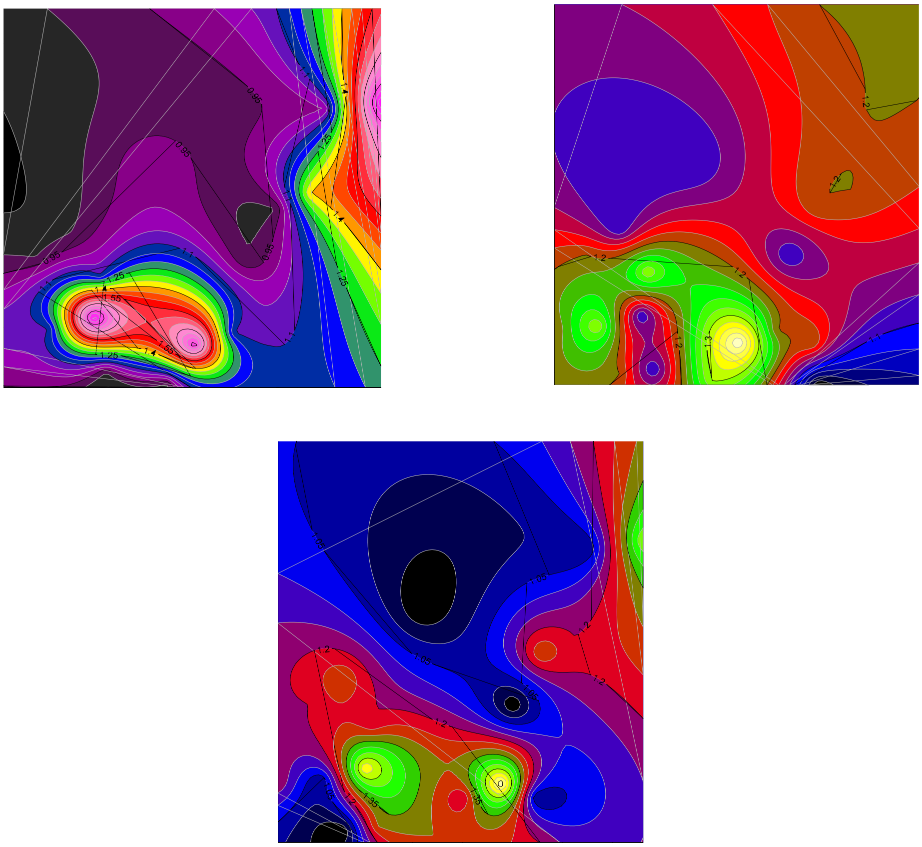


Figure 13: Spatial distribution map of soil magnesium at the study area

c) Relationship between the Soil Properties

i. Relationship between bulk density and soil porosity

The Figure 14 below showed the relationship given by the equation y = -0.553ln(x) + 0.6581with a Coefficient of Determination (**R^2 = 0.9999**) which indicates a strong degree of correlation but an inverse relationship between the bulk density and soil porosity. This means that the Bulk Density predicted 99.9% of the variation captured by the Soil Porosity in the study area. Therefore the model shows that the higher the bulk density of the soil the lower the percentage pore space in the soil irrespective of the depth of the soil. This observation agrees with the work of Mapa *et al*. (1986), Taiwo *et al*. (2016) and Omotade and Alatise (2017).

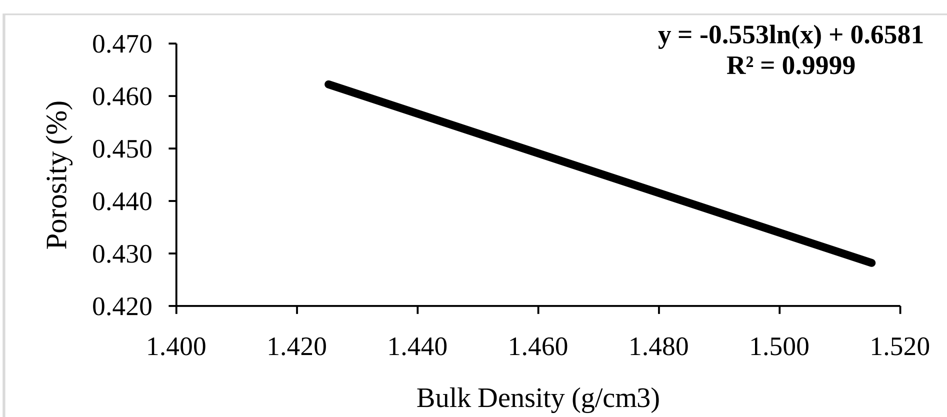


Figure 14: Relationship between Bulk Density and Soil Porosity

ii. Relationship between soil hydraulic conductivity and soil water holding capacity with the depth

The Figure 15 to16 below shows the Relationship between soil hydraulic conductivity and soil water holding capacity with the depth given by the equation $y = -0.0000x^2 + 0.0001x + 0.0081$ and $y = -0.0116x^2 + 0.4806x + 48.788$ respectively with a Coefficient of Determination (R^2 = 1.0) each which indicates a strong degree of correlation. This means that the depth predicted 100% of the variation captured by the soil hydraulic conductivity and soil water holding capacity in the study area. The two parameters affect infiltration of water into the soil and significantly determine the type of irrigation system to be used on the study site. Taiwo *et al*. (2016): Omotade and Alatise (2017).

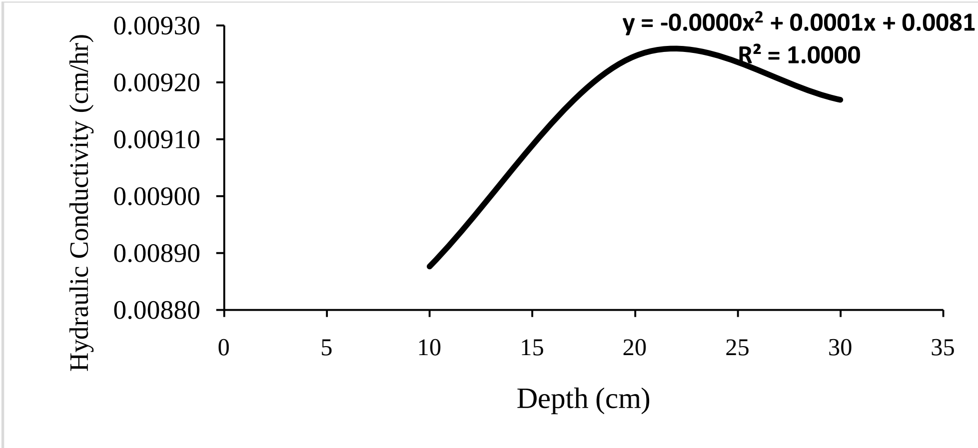


Figure 15: Relationship between Hydraulic Conductivity (cm/hr)and Depth

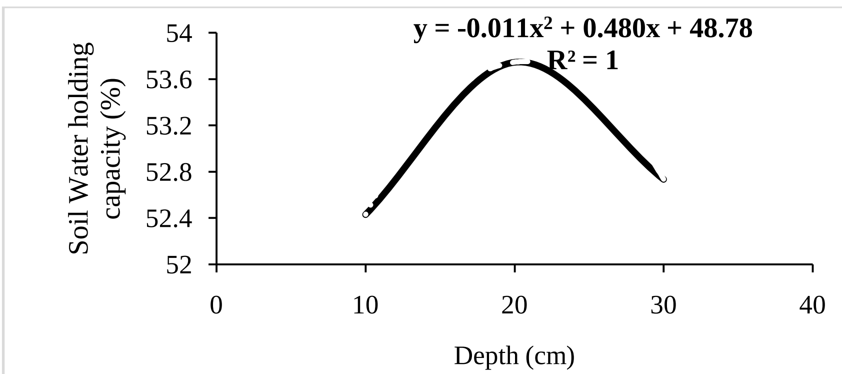


Figure 16: Relationship between Water holding capacity and Depth

iii. *Relationship between the soil moisture content and water holding capacity*

The Figure 17shows the relationship of a model given by the equation y = $-0.063x^2 + 1.7368x + 41.825$ with a Coefficient of correlation ($R^2 = 1$) which indicates an inverse variations and a very strong degree of correlation. This means that the moisture content predicted 100% of the variation captured by the water holding capacity in the study area. Hence the water holding capacity of the soil in the study depends on the soil moisture content of the soil. This observation is in line with the works of Omotade and Alatise (2017). Meanwhile, values for the water holding capacity and soil moisture content at the experimental field are similar to those reported by Taiwo *et al*. (2016) and Omotade and Alatise (2017)

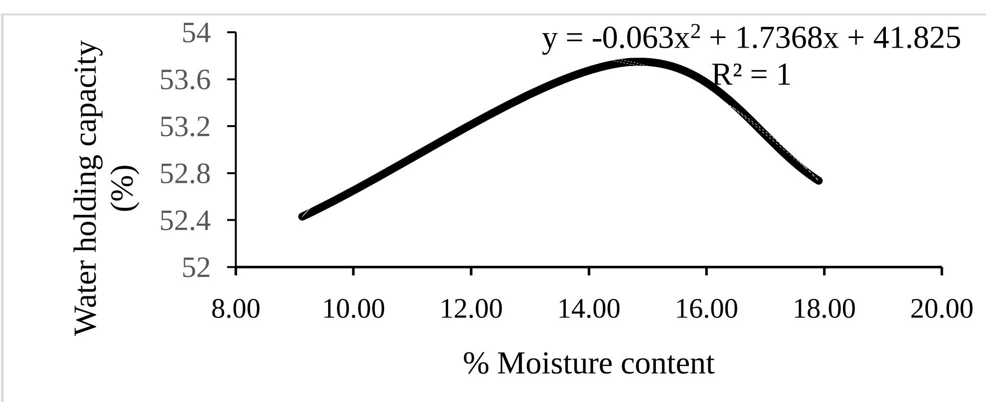


Figure 17: Relationship between soil moisture content and the soil water holding capacity

iv. *Relationship between the soil nitrogen and phosphorus*

The Figure 18shows the relationship given by the equation y = 0.0295x + 0.2129 with a Coefficient of Determination (R^2 = 0.4908) which indicates a weak degree of correlation. This means that the soil nitrogen cannot predict accurately the quantity in cmol/kg of soil phosphorus in the study area. This observation negates the one reported by Omotade and Alatise (2017) which gives the coefficient of correlation of about 92%. This observation could be as a result of the class of soil found in the study area and the dominating plant growing on the field. This can determine the quality and type of organic fertilizers that can be applied to crops grown in the study area.

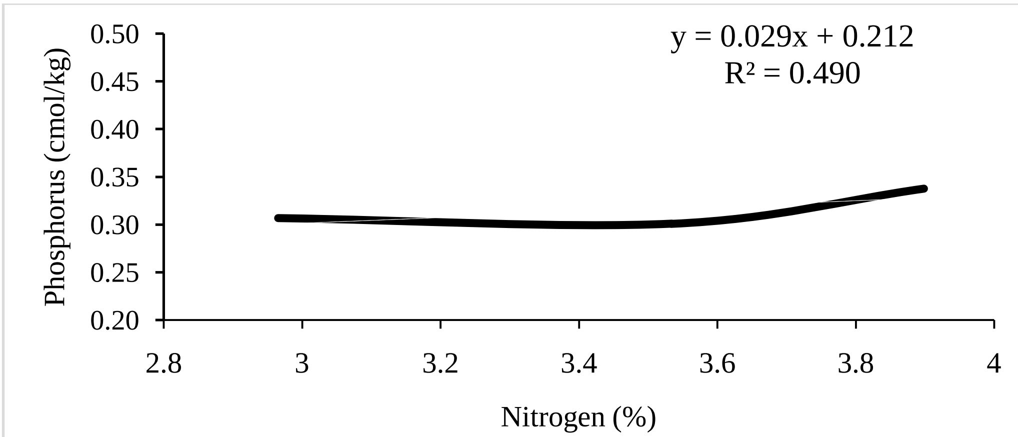


Figure 18: Relationship between Nitrogen (%) and Phosphorus (cmol/kg)

v. *Relationship between Soil organic matter and depth*

The Figure 19 shows an inverse relationship between the soil organic matter and depth given by the equation y = $-0.0015x^2$ + 0.0604x + 2.9237 with a Coefficient of Determination (R^2 = 1) which indicates a strong degree of correlation. This means that the soil organic matter reduces with the depth in the study area this. This observation could be as result of reduced microbial activities, increase and increase in bulk density through the depth and also as a result of the class of soil found in the study area and the dominating plant growing on the field. This can determine the quality, quantity and type of organic fertilizers that can be applied to crops it can also help in predicting suitable crops that can be grown in the study area.

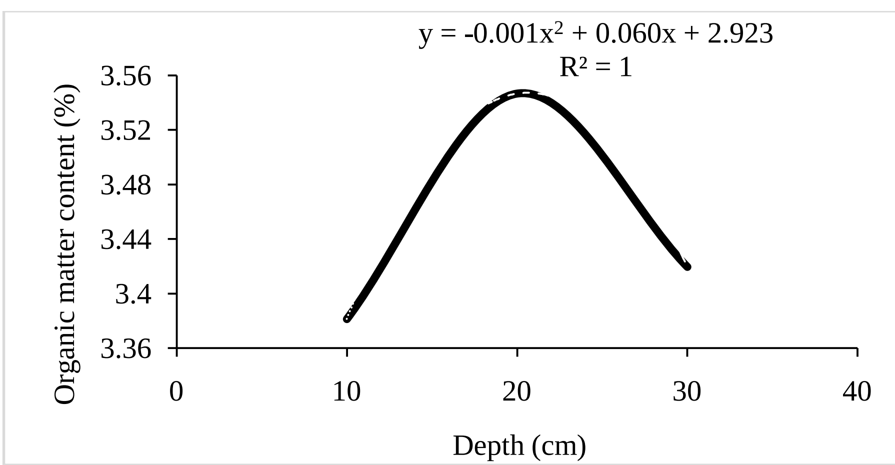


Figure 19: Relationship between Organic matter content (%) and Depth (cm)

IV. Conclusions

The physical properties of the study area as at the time of the study were found to be optimal for crop production. It was observed that about 65% of the bulk density (1.43, 1.43, 1.47, 1.48, 1.49, 1.52,) values were moderate which allows easy movement of water and air for plant development. Moreover, the measurement of the water holding capacity and the hydraulic conductivity of the field is moderate for various water management activities including selection and design of suitable irrigation systems, design of drainage system and for developing different strategies to increase crop productivity.The results of chemical properties also shows the fertility assessment and land use management practices for crop production.75% of calcium was low and continual application of lime is needed in order to maintain the available calcium within the soil. The mean pH value of the soil in the study site was found to be 5.65, 5.64 and 5.72 for depth 10 cm, 20 cm and 30 cm respectively which is found to be slightly acidic which are usually most productive for crop growth. 80% of the CEC distributed is moderate with significant clay organic matter content gives an insight into soil quality and site characteristics of good porosity or internal structure of the soil. The organic matter content is adequate, which is 64% moderate in the soil, and organic matter levels in agricultural soil can be enhanced by crop rotation, residue management and the application of farm manure or organic fertilizers.

Acknowledgement

The study was funded by Dr O. O. Olubanjo and S. O. Ayoola of the department of Agricultural and Environmental Engineering, Federal University of Technology Akure, (FUTA).

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