Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 17 Issue 5 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

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Abstract- The determination of the spatial variability of soil physical and chemical properties enables essential requirement for crop growth and development. The objectives of the study therefore were to determine the soil physical and chemical properties and characterize the spatial variability of soil physical and chemical properties across the study area. The physical and chemical properties determined were bulk density, particle density, Soil Hydraulic Conductivity (SHC),Water Holding Capacity (WHC) and soil pH, Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Cation Exchange Capacity (CEC), Soil Organic Matter (SOM) respectively. The study was conducted at the Agricultural Engineering Research Farm land, the Federal University of Technology, Akure (FUTA). Soil samples were collected from three sampling depths between 0-60cm at an interval of 20cm at different 20 points across the field while coordinates of the soil sampling points were determined using Global Positioning System (GPS) procedures.

Keywords: *soil property, GPS, sampling point, productivity potential.*

GJSFR-D Classification : *FOR Code: 079902*

SPATIALVARIABILITYOFSOILPHYSICALAND CHEMICALPROPERTIESIN AKURESOUTHWESTERNNIGERIA

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Spatial Variability of Soil Physical and Chemical Properties in Akure, South Western, Nigeria

Omotade, I.F [α] & Alatise M.O [σ]

Abstract- The determination of the spatial variability of soil physical and chemical properties enables essential requirement for crop growth and development. The objectives of the study therefore were to determine the soil physical and chemical properties and characterize the spatial variability of soil physical and chemical properties across the study area. The physical and chemical properties determined were bulk density, particle density, Soil Hydraulic Conductivity (SHC),Water Holding Capacity (WHC) and soil pH, Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Cation Exchange Capacity (CEC), Soil Organic Matter (SOM) respectively. The study was conducted at the Agricultural Engineering Research Farm land, the Federal University of Technology, Akure (FUTA). Soil samples were collected from three sampling depths between 0-60cm at an interval of 20cm at different 20 points across the field while coordinates of the soil sampling points were determined using Global Positioning System (GPS) procedures. Results showed that the average textural class was sandy clay loamwhile in physical properties: bulk density, particle density, SHC, WHC were 1.47 g/cm^3, 2.23 g/cm^3, 0.027cm/hr, 41.78 % respectively and chemical properties showed that the soil pH, N, P, K, Ca, Mg, CEC, SOM were 6.43, 0.10%, 1.60 mg/kg, 0.26 cmol/kg, 2.66 cmol/kg, 1.59 cmol/kg, 13.31cmol/kg, 1.69% respectively. It showed that the spatial variability of major soil parameters have influence on the spatial distribution of crop productivity potential. Therefore, the soil physical and chemical properties should be determined after every round of crop production on the field to determine the change in the soil properties.

Keywords: soil property, GPS, sampling point, productivity, potential.

I. Introduction

Soil is a complex, living, changing and dynamic component of the agro ecosystem. It plays an essential role in the biophysical and biogeochemical functioning of the planet. In addition, it is a natural body consisting of layers that are primarily composed of minerals which differ from their parent materials (Basava Raju et al., 2005). Without the knowledge of soil properties, it is not possible to determine soil quality and soil water plant relationship in a given area as well as how it should be managed and conserved. Soil properties are usually recognized as important soil quality indicators and they are significantly controlled by variation in landscape attributes including slope, aspect, and elevation which influence the distribution of energy, plant nutrients, and vegetation. Several studies showed that soil properties vary across farm fields, causing spatial variability in crop yields (Gaston et al., 2001). Variability in soil properties is a direct result of the five soil forming factors: climate, organisms, relief, parent materials and time (Mzuku et al., 2005). 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).

A better understanding of the spatial variability of soil properties is important for refining agricultural management practices and for improving sustainable land use (McGrath and Zhang, 2003). 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. 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). 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% (Alatise, 2010). 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 (Valipour, 2012). The objectives of the study were to determine the soil physical and chemical properties and characterize the spatial variability of the soil physical and chemical properties.

II. Materials and Method

The study was conducted at the Department of Agricultural Engineering research farm land, Federal University of Technology Akure Ondo State, Nigeria. Akure is located on the latitude 7° 14'N and longitude 5° 08'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

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season period. The study was performed within a total marked out size of 2250m^2.

a) Soil Sampling and Laboratory Measurements

Soil samples were randomly collected within the area from three sampling depths 0-20cm, 20-40cm and 40-60cm at 20 different points covering the study area using soil auger. 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 (0-20cm) + (20-40cm) + (40-60cm) accordingly). The sampling points were located on the site using Global Positioning System (GPS) equipment. The highest elevation is 345.82m while lowest level is 344.2m above sea level as shown in Figure 1 with spatial variability of soil attributes in different landscape positions which was determined using geo-statistics techniques.

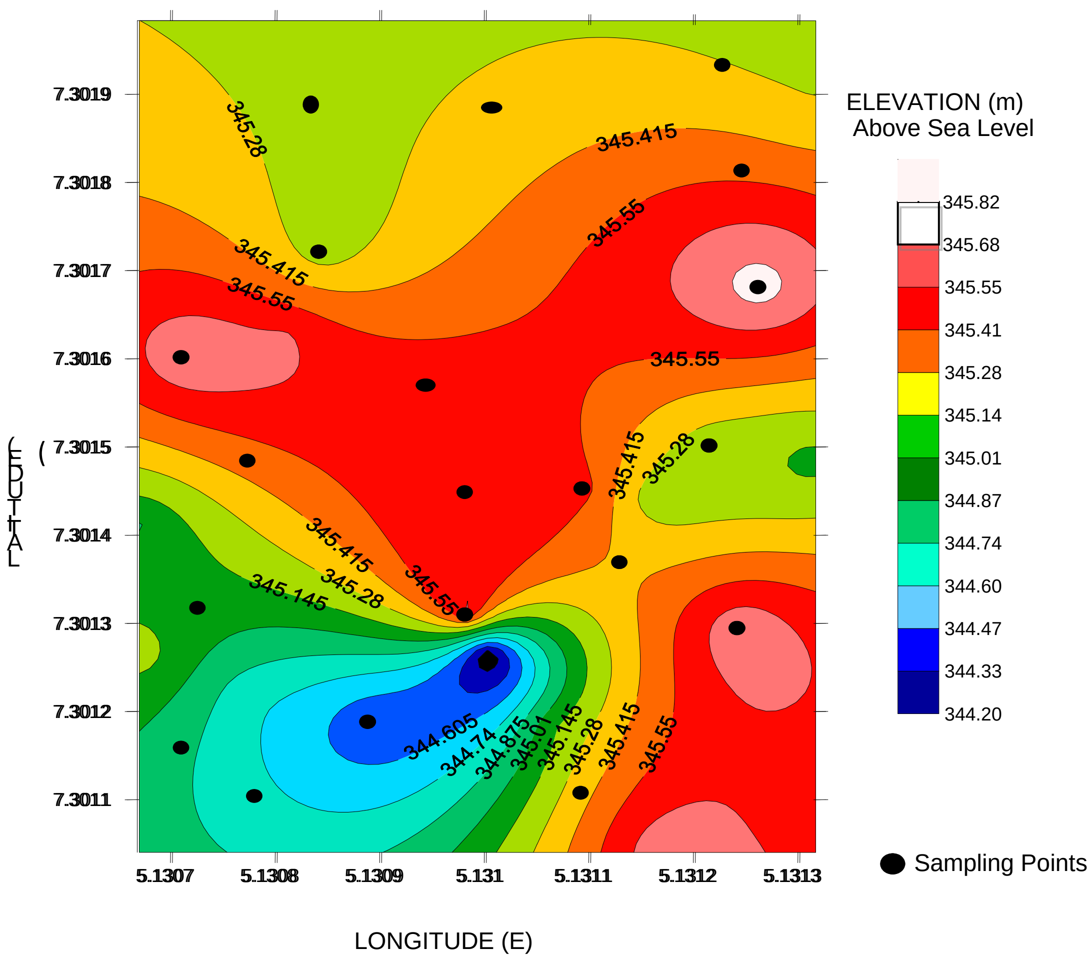

Figure 1: Map showing the elevations of the study area above sea level

The collected soil samples were air- dried and passed through a 2mm sieve and soil moisture content was determined using gravimetric method while the bulk density was determined using core sampler. The soil moisture content, bulk density (using Blarke and Hartage, (1986) and water holding capacity, Particle Density (PD) and Soil Porosity were also determined mathematically. The particle- size distribution (soil texture) was determined by Bouyoucos hydrometer method (Gee and Bouder, 1986). The Soil Hydraulic Conductivity (SHC) was determined using ring infiltrometer method. Soil organic matter content was determined using the modified Walkley-Black wet oxidation procedure (Nelson and Sommers, 1996). Cation Exchange Capacity (CEC), P, Ca^{2+} and Mg^{2+} were extracted using ammonia acetate (Jackson, 1962). K^+ and Na^+ were determined using flame photometer. Soil pH was determined using the digital electronic pH meter. Total nitrogen was determined with Kjeldahl method. The data were subjected to statistical analysis using excel.

Also all data corresponding to each grid point location was spatially interpolated using global positioning system (GPS) and selected data was interpolated using SURFER (Golden Software Inc., Golden, Colorado, USA), software (kriging method).

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III. Results and Discussion

a) Soil Physical Properties at the Study Area

i. Soil Texture and Soil Moisture Content

The result of the soil texture at the study showed that the average clay, silt and sand content were 24.55%, 14.50% and 60.40% respectively. With the proportion of each indicates that the soil at the study area belong to sandy clay loam. Sandy clay loam usually facilitates water infiltrability and nutrients retainability (Shukla and Lal, 2002). Figure 2 showed the graphical representation of moisture content at various depths against the sampled points. The result obtained showed that at each points, the moisture content decreases with increase in depth. The average moisture contents from point A –T at depth 0-20, 20-40, and 40-60 are 13.47%, 11.94% and 9.42% respectively. The soil in the study area showed high amount of moisture at the surface soil (0-20cm) at each sample points, a decrease in moisture at the depth (20-40cm) and depth (40-60cm). High moisture content at depth 0-20cm could be attributed to the presence of organic matter at the surface layer of the soil and as water percolates into the soil, moisture content decreases along the depth. In figure 3, points H, L and N have high difference of moisture content in depth 0- 40cm compared to depth 40- 60cm as their water holding capacity ranges at different depth. These differences were due to the variation in the depth, clay, silt and organic carbon content in the soils (Thangasamy et al*.,* 2005).

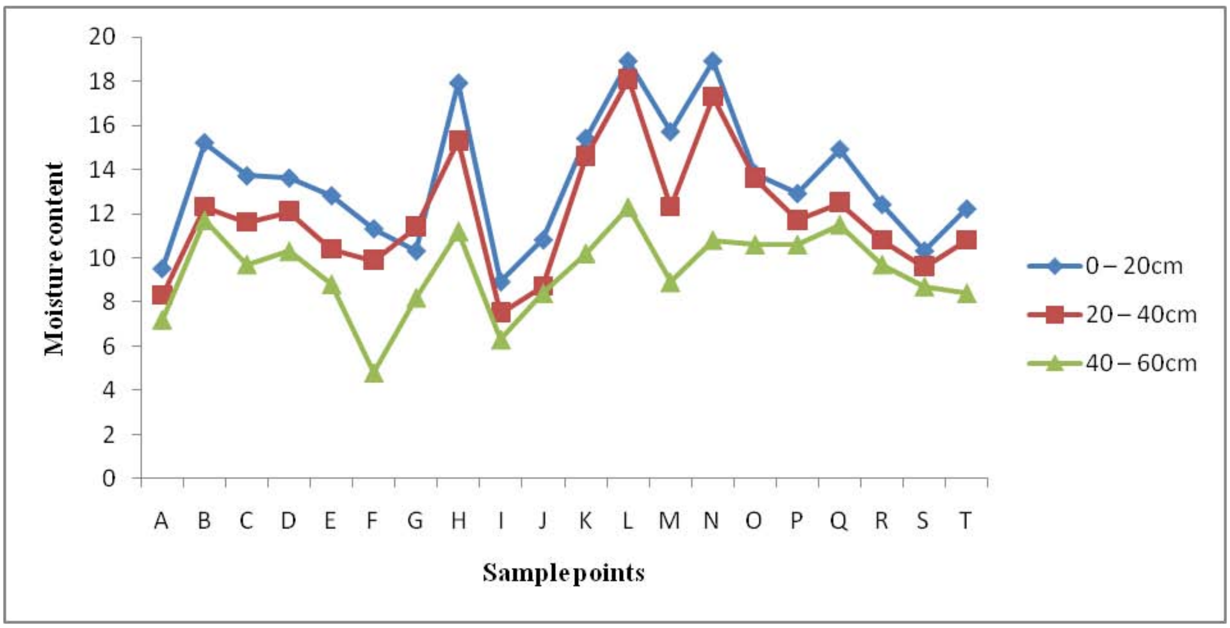

Figure 2: Moisture content of 20 sample points at different depths

Table 1 gives the comprehensive values of the physical properties of the soil obtained at each different point and the average values in the study area. The average bulk density value of the study area was found to be 1.47g/cm^{-3}, and an ideal soil according to (Hoorman et al., 2011) has a bulk density of about 1.25 g cm^{-3} but a compacted soil has a bulk density of 1.5 g cm^{-3} or higher, which invariably means that the soil at the study area has been compacted due to raindrop impact on the soil and animal grazing. The soil porosity showed a relative difference across the study area, and some few points showed lower level of porosity (< 30.00%). The soil porosity is being influenced by the soil texture and the bulk density. The Water Holding Capacity (WHC) ranged significantly from 40.30 to 43.54%, the high sand content in the soil could only enable such amount of water to be retained in the soil as it has low retain ability of moisture. The Particle Density (PD) also varied significantly across the study area. The average Soil Hydraulic Conductivity (SHC) of the study area was found to be 0.027cm/hr and it did not show any significant difference across the points.

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Table 1: Soil Physical Properties at the Study Area

Points	B.D(g/cm^3)	Porosity (%)	P.D (g/cm^3)	SHC (cm/hr)	WHC (%)
A	1.5	34.5	2.29	0.02	42.45
B	1.5	29.2	2.12	0.022	41.55
C	1.5	26.11	2.03	0.024	40.5
D	1.5	35.9	2.34	0.025	42.48
E	1.49	29.72	2.12	0.026	40.52
F	1.49	26.96	2.04	0.027	42.16
G	1.48	34.22	2.25	0.027	41.45
H	1.48	28.85	2.08	0.027	42.23
I	1.48	36.21	2.32	0.027	40.3
J	1.47	32.26	2.17	0.028	42
K	1.47	36.36	2.31	0.028	41.4
L	1.47	30.99	2.13	0.029	43.32
M	1.47	39	2.41	0.029	42.45
N	1.46	35.11	2.25	0.029	41.45
O	1.46	37.61	2.34	0.03	43.54
P	1.46	31.78	2.14	0.03	41.35
Q	1.45	34.39	2.21	0.03	41.25
R	1.45	35.27	2.24	0.03	40.32
S	1.45	39.08	2.38	0.03	42.45
T	1.45	38.03	2.34	0.03	42.35
AVERAGE	1.47	33.58	2.23	0.027	41.78

B.D = Bulk density, P.D = particle Density, Ave MC = Average Moisture Content, SHC = Soil Hydraulic Conductivity, WHC= Water Holding Capacity

b) Soil Chemical Properties

Table 2 below showed the result of the soil chemical properties present at the study site. The pH of the soil in the study site was found to be 6.43 which is 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). The CEC's across the study area spatially varied within the range of 14.54 to 12.32cmol/kg, with the average value of 13.31cmol/kg. Soil Cation Exchange Capacity (CEC) has been classified as low (<6cmol/kg), medium (6-12cmol/kg) and high (>12cmol/kg) according to Adepetu et al., (1979). The values of the soil CEC at the study area fell within the high range based on this classification since their values were above 12cmol/kg. The presence of these high CEC values is influenced by high clay content, organic matter and the soil pH (Noma et al., 2005 and (Hazleton and Murphy 2007)). The Organic matter (OM) content found in the study area varied from low (0.76%) to high (3.04%). The deduced values of the Phosphorus (P), Nitrogen (N), Potassium (K), Calcium (Ca) and Magnesium (Mg) content in the soil at the study site were 1.60 mg/kg, 0.10%, 0.26cmol/kg, 2.66cmol/kg and 1.59cmol/kg respectively.

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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.

Table 2: Soil Chemical Properties at the Study Area

Points	pH	OM (%)	CEC (cmol/kg)	P (mg/kg)	N (%)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
A	6.25	0.76	12.36	1.32	0.16	0.25	3.9	1.7
B	6.57	0.83	12.5	1.8	0.06	0.24	2.5	1.1
C	6.13	0.97	12.52	1.79	0.04	0.26	2.1	0.7
D	5.98	1.06	14.34	1.56	0.07	0.27	2.34	2.56
E	5.86	1.34	13.56	1.74	0.05	0.24	2.45	1.76
F	6.3	1.36	12.54	1.55	0.15	0.25	2.65	1.56
G	6.43	1.38	13.4	1.76	0.08	0.24	2.76	1.64
H	6.84	1.45	14.54	1.47	0.15	0.27	2.54	1.63
I	6.26	1.56	12.5	1.65	0.09	0.28	2.89	1.6
J	6.67	1.67	14.36	1.39	0.06	0.26	2.65	1.74
K	6.56	1.68	12.56	1.59	0.13	0.24	2.45	1.67
L	6.85	1.56	14.35	1.72	0.07	0.26	2.64	1.5
M	6.52	1.76	12.34	1.58	0.08	0.29	2.73	0.8
N	6.45	2.11	14.35	1.65	0.13	0.27	2.48	1.73
O	6.65	1.89	12.36	1.48	0.09	0.25	2.76	1.45
P	6.17	2.11	12.56	1.65	0.14	0.28	2.5	1.72
Q	6.32	2.3	12.32	1.73	0.18	0.26	2.89	1.7
R	6.45	2.34	14.35	1.63	0.16	0.25	2.78	1.78
S	6.78	2.55	14.2	1.48	0.06	0.23	2.6	1.68
T	6.58	3.04	14.26	1.5	0.05	0.24	2.68	1.85
Average	6.43	1.69	13.31	1.6	0.1	0.26	2.66	1.59

OM = Organic matter, CEC = Cation Exchange Capacity, N = Nitrogen, Mg = Magnesium, Ca = calcium, K = Potassium, P = Phosphorus

c) Relationship between the soil properties

i. Relationship between the soil moisture content and water holding capacity

The Figure 3 below showed the relationship of a model given by the equation Y =2.1x – 76.5 with a Coefficient of Determination (R^2 = 0.96) which indicates a strong degree of correlation. This means that the moisture content predicted 96% of the variation captured by the water holding capacity in the study area.

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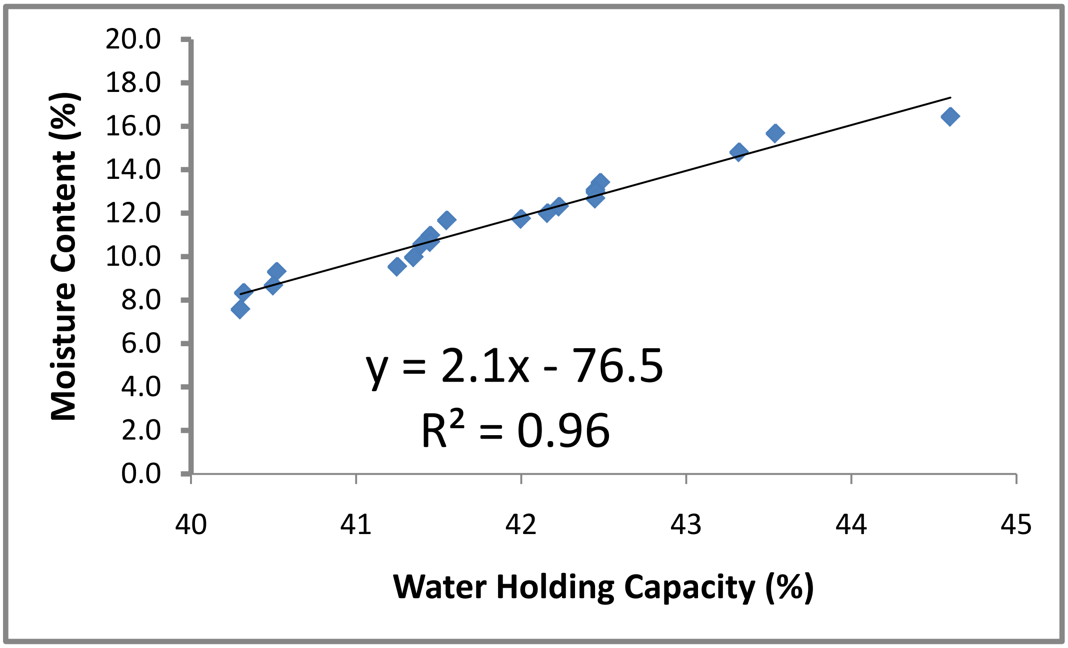

Figure 3: Relationship between soil moisture content and soil water holding capacity

ii. *Relationship between the soil nitrogen and phosphorus*

The Figure 4 below showed the relationship given by the equation Y= 0.34x - 0.46 with a Coefficient of Determination (R^2 = 0.92) which indicates a strong degree of correlation. This means that the soil nitrogen predicted 92% of the variation captured by the soil phosphorus in the study area. This can determine the quality and type of organic fertilizers that can be applied to crops grown in the study area.

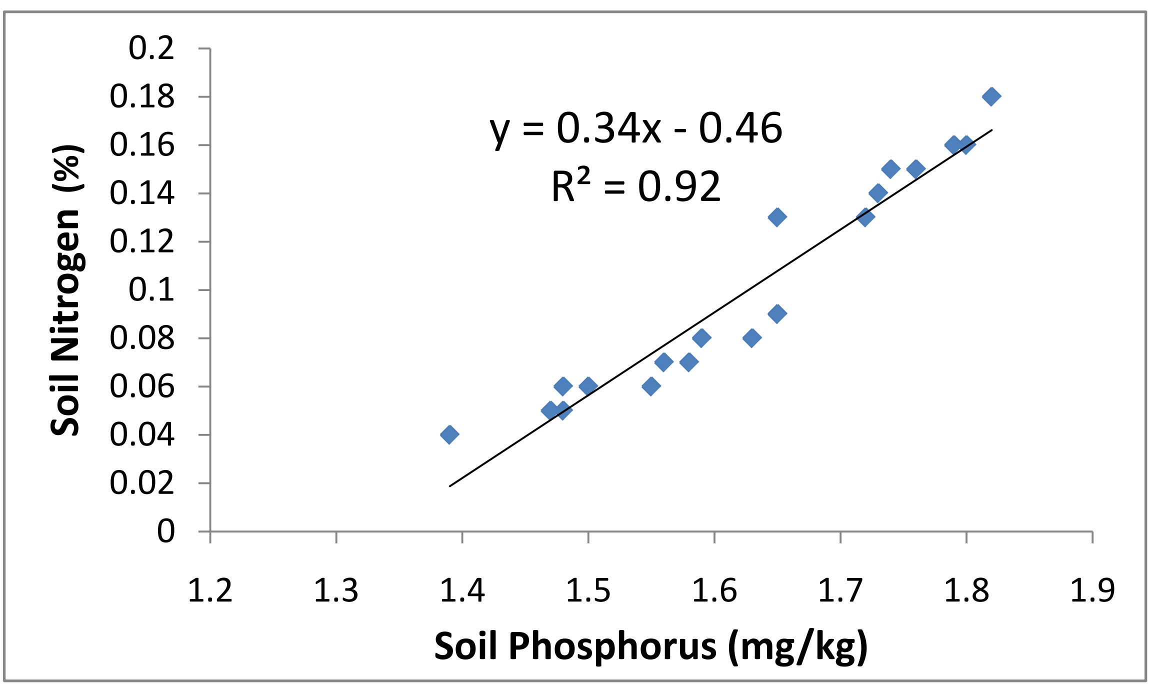

Figure 4: Relationship between Soil Nitrogen and Soil Phosphorus

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iii. *Relationship between bulk density and soil porosity*

The Figure 5 below showed the relationship given by the equation y = -206.1x + 337.4 with a Coefficient of Determination (R^2 = 0.92) which indicates a strong degree of correlation. This means that the Bulk Density predicted 92% of the variation captured by the Soil Porosity in the study area.

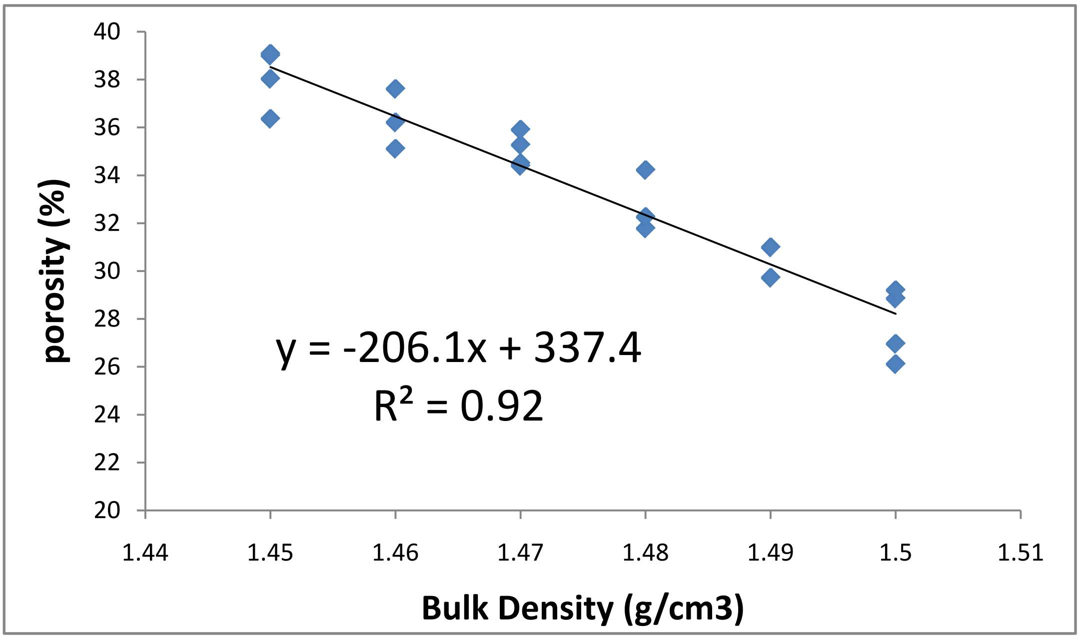

Figure 5: Relationship between Bulk Density and Soil Porosity

iv. *Relationship between soil hydraulic conductivity and bulk density*

The Figure 6 below showed an inverse relationship between the soil hydraulic conductivity and bulk density given by the equation Y= -0.15x + 0.25 with a Coefficient of Determination (R^2 = 0.87) which indicates a strong degree of correlation. This means that the soil hydraulic conductivity predicted 87% of the variation captured by the bulk density 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.

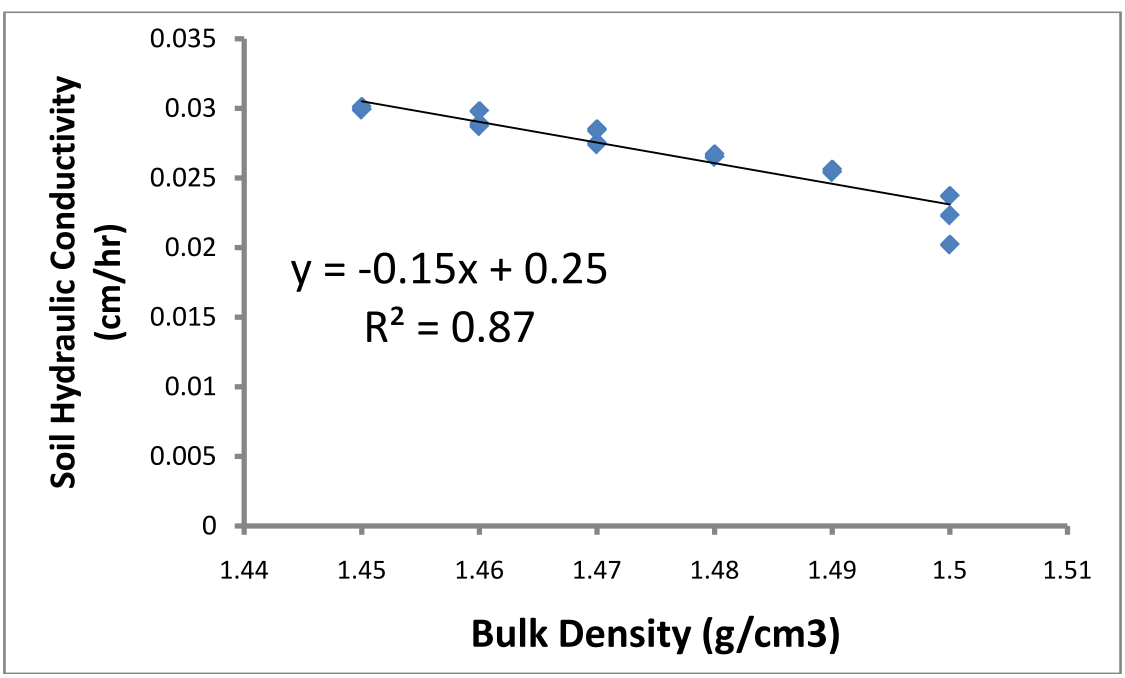

Figure 6: Relationship between Soil hydraulic conductivity and Bulk Density

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v. *Relationship between Soil organic matter and bulk density*

The Figure 7 showed an inverse relationship between the soil organic matter and bulk density given by the equation y = -30.90x + 47.23 with a Coefficient of Determination (R^2 = 0.89) which indicates a strong degree of correlation. This means that the soil organic matter predicted 89% of the variation captured by the Bulk density in the study area.

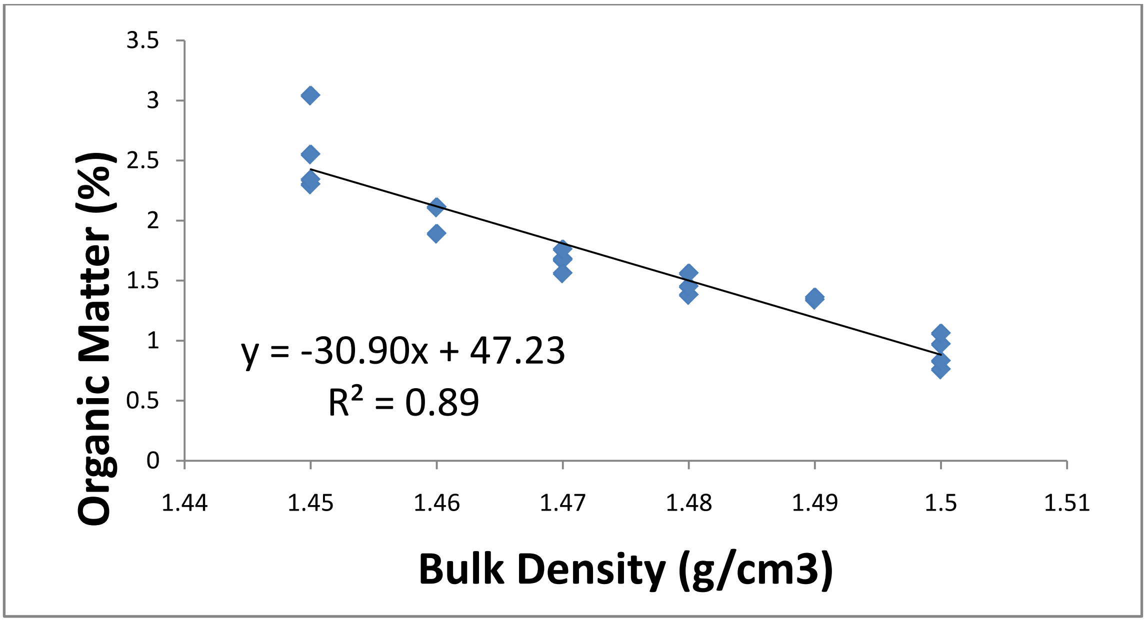

Figure 7: Relationship between Soil Organic Matter and Bulk Density

d) *Spatial variability of some of the soil properties at the study area*

The range of the properties were analysed into three different categories such as high, moderate and low. The soil properties were spatially distributed across the study area. The physical properties had some evenly distributed attributes. Also, the chemical properties had similar distribution of the properties. The spatial variability maps are as shown in the following figures.

i. *Spatial Variability of the Soil Moisture Content*

Figure 8 shows spatial pattern of the soil moisture content. Soil with high moisture content values between the range 16.1% to 19.2% were observed at the northeast, southwest and eastern part in small proportion at three different parts of the field. This could be attributed to the increase in organic C, silt and clay content. Moderate moisture content between 12.3% and 16.1 % stretched from the northeast to the southeast and western part of the field. Low moisture content between the range of 8.5% and 12.3% stretched in a large proportion from the north through the northeast to the south western part of the field. The low moisture content in the zone could be attributed to the presence of sandy soil due to high rate of infiltration in the soil. Findings have shown that soil texture has a significant effect on soil moisture content of agricultural soil as water is held more tightly in small pores and in clay (Krull et al. 2004)

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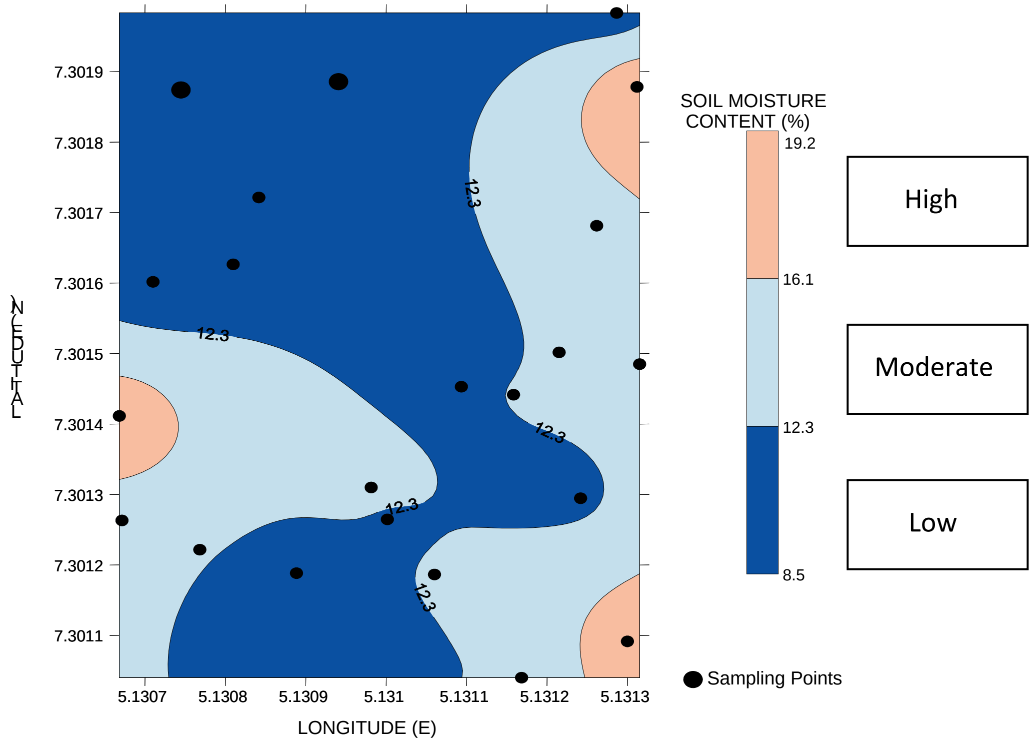

Figure 8: Spatial distribution map of soil moisture content at the study area

ii. *Spatial Variability of the Soil Hydraulic Conductivity*

Hydraulic conductivity is a very important soil property because it affects the response of the soil to water and nutrient movement. As shown in Figure 9, high hydraulic conductivity values between the range 0.0278cm/hr to 0.0301cm/hr were observed from the northern and the southeast region. This could be attributed to the particle and pore size distribution due to the presence of sand and silt of the soil in the region. Moderate Hydraulic conductivity ranged between 0.0239cm/hr to 0.0278cm/hr stretched from the northeast to the middle and to the south west region. Low hydraulic conductivity between the range of 0.020cm/hr and 0.0239cm/hr were observed at the north and the middle of the field in a small proportion. Findings have shown that variability of soil properties such as soil texture, soil structure and some other chemical properties have appreciable effects on infiltration process

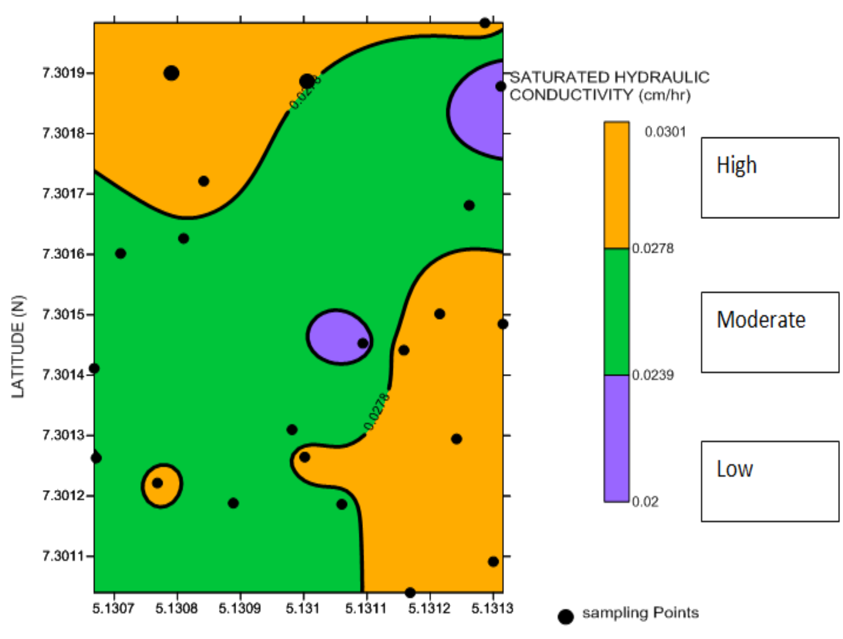

Figure 9: Spatial distribution map of soil hydraulic conductivity at the study area

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iii. *Spatial Variability of Soil Water Holding Capacity (WHC)*

Figure 10 shows the spatial pattern of the soil water holding capacity. High water holding capacitybetween the range 42.36% and 43.54% at the north and the southwest region. The high water holding capacity at these region could be atrributed water content variation, bulk density, particle size distribution, soil texture (clay content), organic matter and level of compaction. Medium water holding capacity between the range of 42.36% and 41.26% dominated the largest portion of the field. Also, low water holding capacity between the range of 40.2% and 41.28 % was observed at the middle south east corner of the field. The level of water holding capacity on the field enables the optimum practice of irrigation.

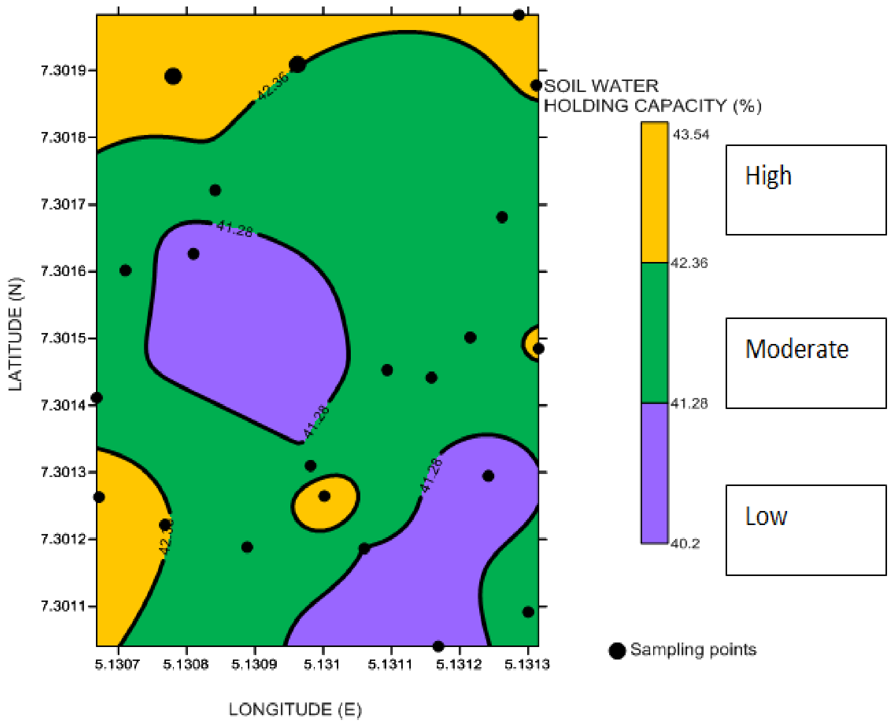

Figure 10: Spatial distribution map of soil water holding capacity at the study area

iv. *Spatial Variability of the Soil Nitrogen*

Figure 11 showed the spatial pattern of nitrogen in the soil. High nitrogen values between the ranges of 0.16% to 0.18% were observed at the southern region of the field in a small proportion. Moderate nitrogen values between the ranges 0.1% to 0.16%stretched from the North West, eastern and to the south eastern region of the field. Low nitrogen values between the ranges of 0.04% to 0.10% stretched from the western region towards the south eastern region at a larger distribution. According to Isirimah et al., (2003) low content of nitrogen in the soil is as a result of leaching caused by erosion and low organic matter.

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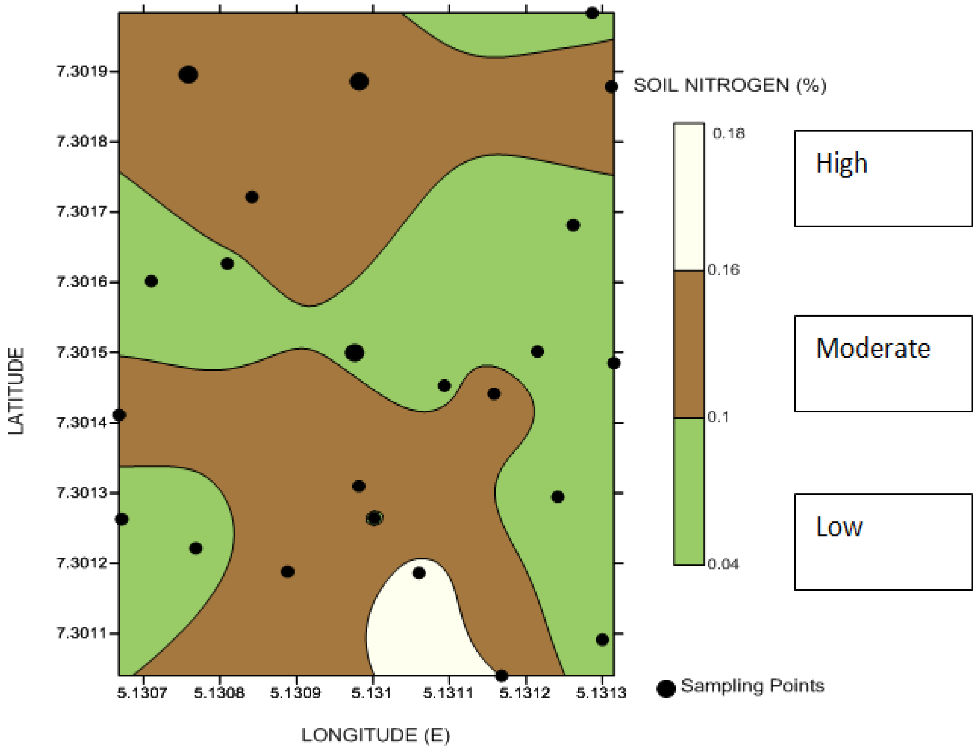

Figure 11: Spatial distribution map of soil nitrogen at the study area

v. *Spatial Variability of the Soil Phosphorus*

In figure 12, there is high phosphorus content at the eastern part stretching towards the middle and at the south eastern end but with a smaller distribution in the western part between the range of 1.68 mg/kg and 1.80 mg/kg. The phosphorus is moderate at the south western region between the range of 1.50 mg/kg and 1.68 mg/kg. Phosphorus is low at the north western region stretching to the north eastern corner between the range of 1.32mg/kg and 1.50 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.

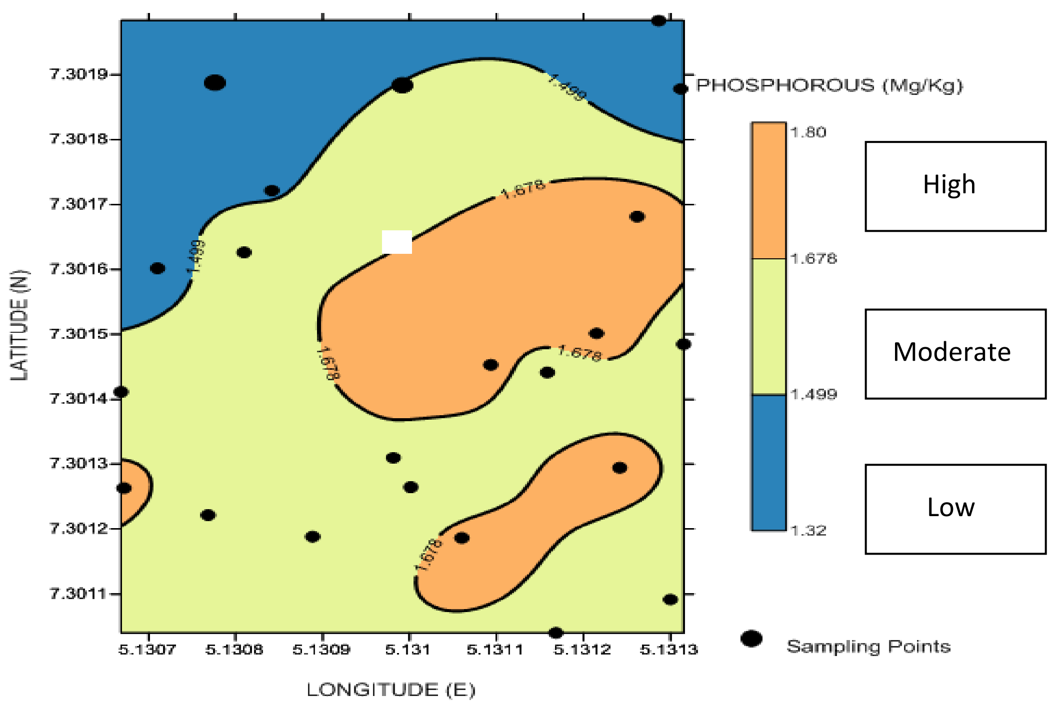

Figure 12: Spatial distribution map of soil phosphorus at the study area

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vi. *Spatial Variability of the Soil Potassium*

The spatial map on Figure 13 showed the distribution of potassium on the field. High variability of potassium values distribution between the range 0.28mg/kg to 0.29 mg/kg were observed at the middle and south western region of the field. Moderate potassium values distribution between the range of 0.25 mg/kg to 0.28 mg/kg stretched from the north east to the south eastern part of the field. Soils with high clay content and organic material can hold or have good reserves of potassium. Low potassium values between the ranges of 0.23 mg/kg to 0.25 mg/kg dominated half of the field as it stretched from the north through the east to the south eastern region of the field. Deficiency of potassium in soil is as a result of higher rainfall because potassium is a mobile nutrient that leaches in sandy soil.

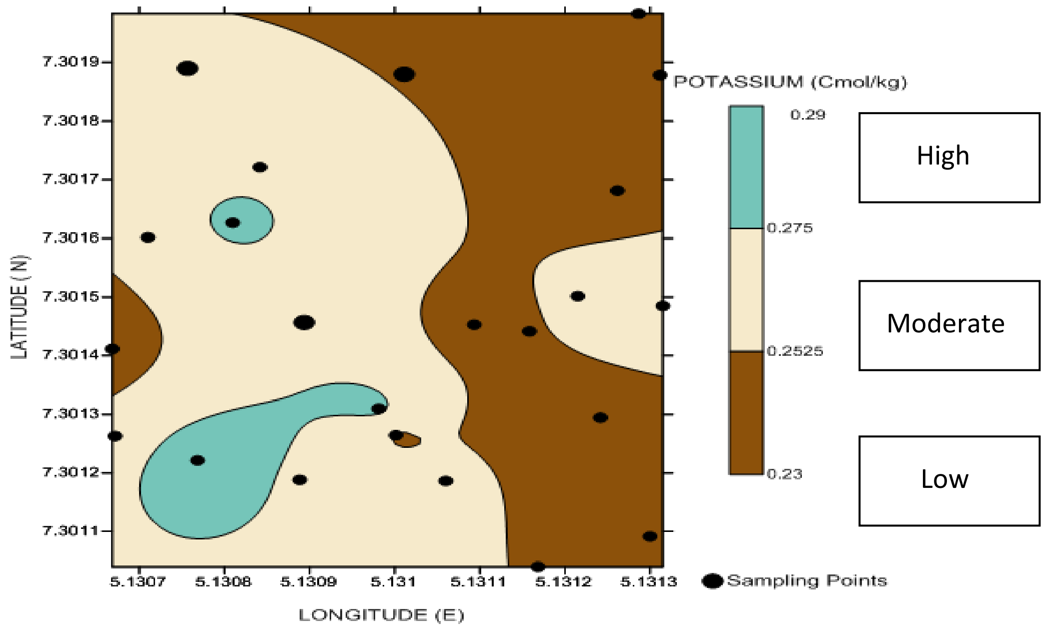

Figure 13: Spatial distribution map of soil potassium at the study area

Table 3: Descriptive statistics analysis of the soil physical and chemical properties

	Min	Max	Range	Mean	SD	CV
pH	5.86	6.85	0.99	6.43	0.27	0.04
P (mg/kg)	1.32	1.8	0.48	1.6	0.13	0.08
N (%)	0.04	0.18	0.14	0.1	0.04	0.45
OM (%)	0.76	3.04	2.28	1.59	0.59	0.35
K (cmol/kg)	0.23	0.29	0.06	0.26	0.02	0.06
Ca (cmol/kg)	2.1	3.9	1.8	2.66	0.35	0.13
Mg (cmol/kg)	0.7	2.56	1.86	1.59	0.39	0.24
CEC (cmol/kg)	12.32	14.54	2.22	13.31	0.92	0.07
WHC (%)	40.3	43.54	3.24	41.77	0.93	0.02
P.D (g/cm^3)	2.03	2.41	0.38	2.22	0.11	0.05
SHC (cm/hr)	0.02	0.03	0.01	0.03	0	0.1
Bulk density (g/cm)	1.45	1.5	0.05	1.47	0.02	0.01
Moisture content (%)	4.1	19.6	15.5	11.67	3.4	0.29

CV = Coefficients of variation SD = Standard deviation Min = Minimum Max = Maximum

According to the classification proposed for CV by Warrick and Nielsen (1980), variability for classification of soil variables is low when CV is lower than 12%, medium when CV ranges from 12 to 60% and high when CV is higher than 60%. It was observed that values of the soil properties such as bulk density, SHC, WHC, pH, P, CEC, P.D showed low variability of data, that is, CV < 12% and N, OM, Ca, Mg, Moisture Content showed a medium variability of data, that is, CV ranges from 12 to 60% (Table 3). Nitrogen (N) has the highest

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CV of 0.45 (45%), and bulk density has the lowest CV of 0.01 (1%) which could be linked to the heterogeneity of land use pattern and landscape position. The variability of a soil attribute can be classified by Warrick and Nielsen (1980) based on CV. The variability of some of the soil physical and chemical properties such as bulk density, WHC, P.D P, K, pH, Ca, Mg and CEC presented a low value of CV in the field. However, OM and N attributes presented a high CV. Among the attributes analyzed, it was observed that greater values of CV occurred in the region with the lowest elevation of the area indicating a greater variability in this area and a smaller portion of the properties. The main soil chemical attributes of interest to this study are soil moisture content, water holding capacity, Mg, pH, Ca, N, P, K, CEC and soil organic matter, as these attributes mostly impact on crop production

IV. Conclusion

The spatial variability of the soil textural class at FUTA was sandy clay loam with a minimum variability of moisture content which was determined using Standard Procedures and equipment. This is not necessary since it has been captured in your discussion. The soil contains a lot of voids for water infiltrability and air movement which gives a low ability to retain moisture. Since the soil is sandy and has high infiltration rate, there is therefore the need for controlled application of water such as drip irrigation system is suggested for this type of soil. Also, the soil in the study area was found to be slightly acidic and it is suitable for agricultural crops. Studies have shown that soils with a high pH have nutrients; therefore the soil at the study area would require little or no application of fertilizers for optimum yields. In this study, the result showed that the spatial variability of soil properties is not completely disordered, but has structure.

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