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Spatial Variability of Soil Physical Properties of A Typical Fadama Farmland (Ayede-Ogbese) In South Western, Nigeria

Ojo, A.S. and Alatise, M.O

Department of Agric. and Environmental Engineering, Federal University of Technology, Akure

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A B S T R A C T

Spatial variability of soil physical properties of Fadama land in Ayede-Ogbese, Ondo state, Nigeria was investigated to determine the suitable irrigation system for the agricultural land. Soil samples at varying depths 0 – 30, 30 – 60 and 60 – 90cm were collected and analyzed using standard methods and procedures. The coordinate of each of the points were obtained with GPS (Global Positioning System). The physical properties investigated include: textural class, bulk density, particle density and moisture content. Others were water holding capacity, total porosity, hydraulic conductivity and organic matter content. Results showed that the soil of the study area belongs to four different textural classes: sandy loam, clay loam, clay and sandy clay loam. The sandy clay loam was dominant with 46% proportion of the prevalent soil textural class in the study area. The mean values for bulk density and moisture content across the depth of 0 – 90cm were (1.30 ± 0.1) g/cm3 and (17.4% ± 7.10) respectively. The mean values for Water Holding Capacity and the Hydraulic Conductivity were (26.2% ± 4.37) and (0.26cm/hr ± 0.13) respectively. The average mean values of soil parameters within the study area were within acceptable limit for optimum agricultural production (FAO/IIASA, 2008). Hence the soil physical properties obtainable at Ayede-Ogbese Fadama land are suitable for the design of sprinkler and drip as appropriate irrigation systems for the study area (FAO/IIASA, 2008).

1. Introduction

Fadama is a local language (Hausa) meaning a river/coastal flood plain or valley bottoms with a high water table susceptible to seasonal flooding (Alatise, 2004a). Water is often available on these flood plains throughout the dry season either as flows in the river, pond or in the river channel or saturated sands close to the surface (Wardrop, 1992)

Soil properties of Fadama lands are of importance in determining the type and extent of irrigation required for agricultural production. Effective irrigation should ensure soil and water compatibility to avoid adverse effects on soil properties. (Abou, 2000).

River Ayede-Ogbese is the third largest in Ondo State (Alatise, 2004b). Over the years, little has been done by the relevant authorities and individuals to harness the huge potentials of the river and its flood plains. The much that has happened along the flood plains are some groups of farmers cultivating in a small scale during the dry seasons. The activities of these farmers are largely without scientific knowledge of the essence and adaptability of physical properties of the prevailing soil in the area.

Consequently, this study investigated the soil physical characteristics of the Fadama lands of Ayede-Ogbese, Ondo State south western Nigeria for sustainable agricultural production.

Correspondence:
E-mail address: femajok2005@yahoo.co

2. Methodology

2.1 *The Study Area*

The study area is the Fadama land of Ayede-Ogbese River, Ondo State, southwestern, Nigeria. The Fadama area lies within latitude 7o12'N and longitude 5o01'E. The area is classified under humid tropical zone (Jagtab and Alabi, 1997). A map of Ondo state showing the Fadama irrigable area and major rivers in the state including the Ayede-Ogbese River is shown in Figure 1. Also, the detailed map of Ayede-Ogbese town showing the Fadama land, the river and the study area is presented in Figure 2.2. The total land mass of the study area is about 1 hectare.

2.2 *Determination of Soil Physical Properties of Ayede-Ogbese Farm Land*

Soil samples were randomly taken with soil auger from 50 points at various depths and interval of 0 – 30, 30 – 60 and 60 – 90cm soil layers and the coordinates of each of the points obtained with

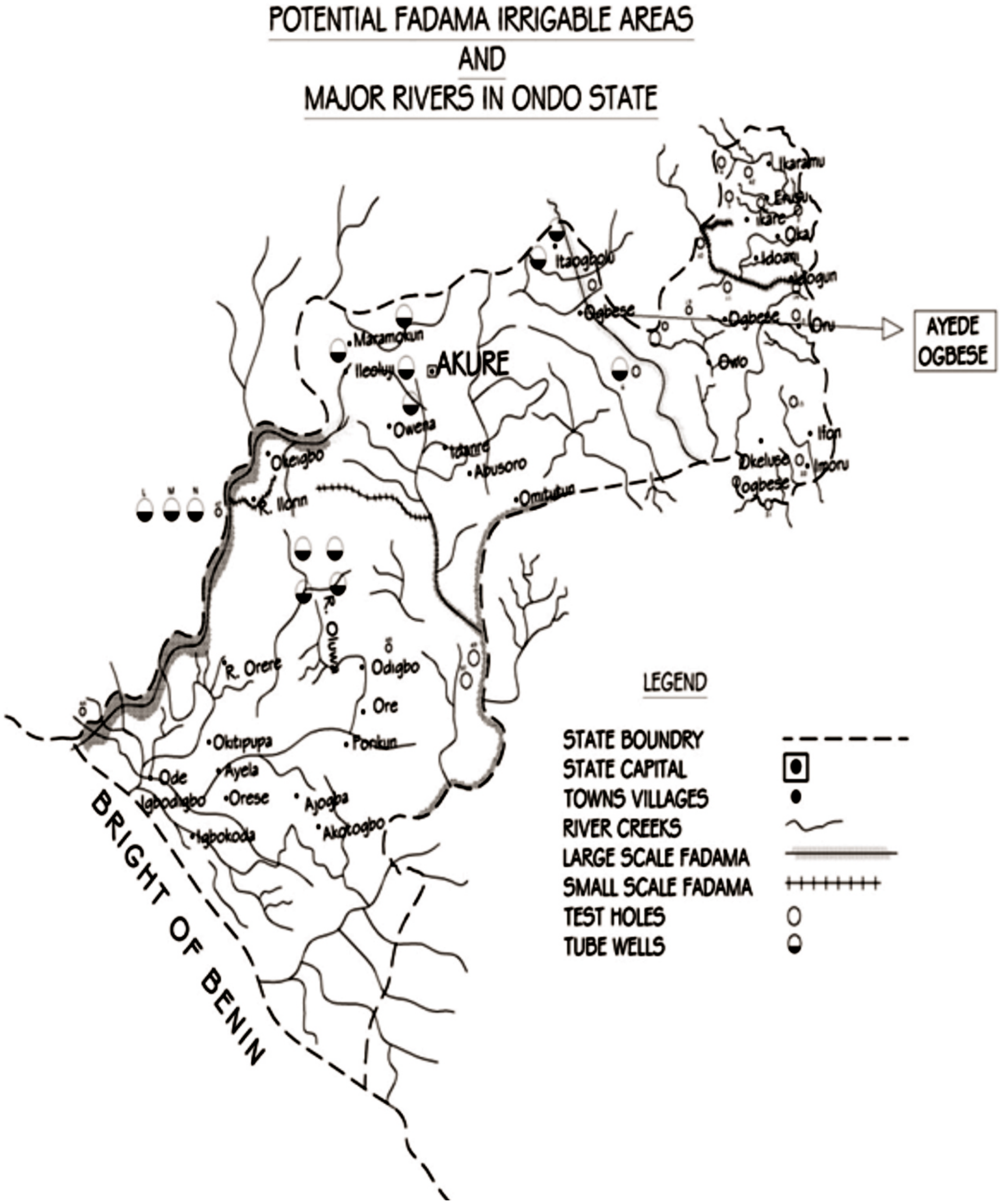

Figure 1: Map of Ondo State showing the *Fadama* irrigable areas and major rivers

GPS (Global Positioning System),Datum WGS84. The Bulk density (Db) and Moisture content were determined by gravimetric method. The mass was taken and the volume calculated from the mass and density of water displaced by the soil sample

$$D_p = \frac{d_w\,(W_s - W_a)}{(W_s - W_a) - (W_{sw} - W_w)} \qquad 1$$

Porosity was obtained using the core sampler and mathematically expressed as the percentage ratio of the total pore volume by the bulk soil volume.

$$Porosity = \frac{total\ pore\ volume}{bulk\ soil\ volume} \qquad 2$$

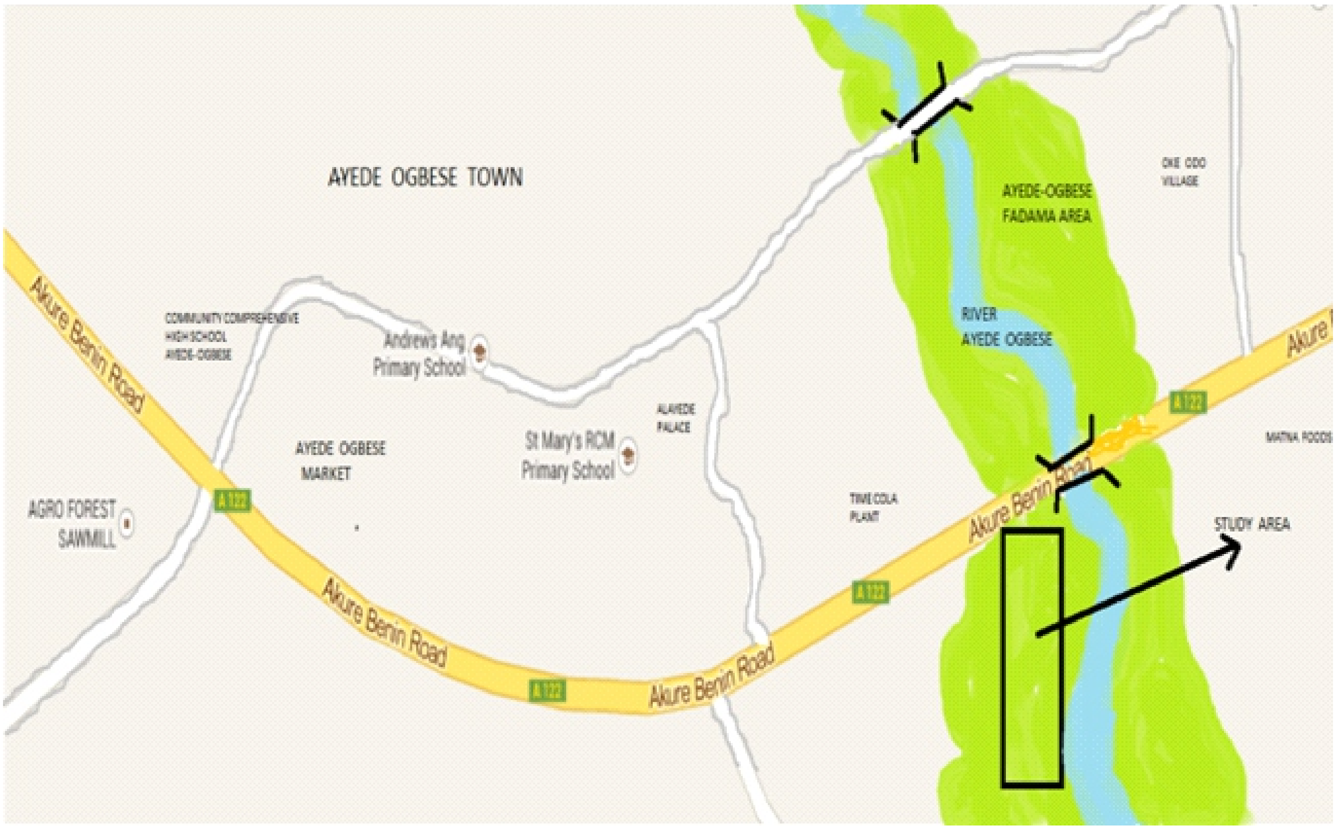

Figure 2: Map of *Ayede*-Ogbese Town showing the *Fadama*land, the River and the Study Area

The Water Holding Capacity (WHC) was determined from the ratio of the maximum water absorbed by soil to the oven-dried weight of the soil (Brady, 1990) while the Soil Hydraulic Conductivity (SHC) was conducted with the use of mini-disc infiltrometer (version 10), 2012, (Zhang, 1997). Particle Size analysis was carried out by hydrometer method (Hansen et al., 1980). The textural class was determined with the aid of textural triangle (FAO/IIASA, 2008). Soil Organic Matter was determined by Walkey-Black wet oxidation method (Franzmeier et al, 1995).

3. Results and Discussion:

3.1 Textural Classification of Ayede-Ogbese Farm Land

The textural class of the study area (about 1 hectare land mass) is presented in Table 1. The textural classes found within the study area ranged from Sandy Clay Loam, Clay Loam, Clay and Sandy Loam. Further analysis of the soil class showed that Sandy Clay Loam proportionally occupied about 46%, while Clay loam, sandy loam and clay occupied 30%, 18% and 6% respectively.

Presence of significant quantities of sand and clay as a major soil particle element may be linked with periodic deposition of these soil particles as a result of flooding during the peak of rainy season. Blake and Hartge (1986) remarked that variations in the clay and sand contents have a significant effect in the physical properties of the soils. Soils with low clay contents, but with high sand content have been found to have higher infiltration and hydraulic conductivity values.

3.2 Bulk Density (BD)

The descriptive statistics of bulk density from the spatial map presented in Figure 2 shows that the minimum and maximum bulk densities were 1.11g/cm3 and 1.58g/cm3 respectively for the top soil (0-30cm). The mean bulk density for the depth (0-30cm) in the study area was 1.30g/cm3. The mean bulk density is suitable for crop production, development and yield (FAO, 1979). This was due to the fact that root development in plant growth is associated with moderate soil bulk density (FAO, 1979).

The bulk density values within the study site were 8 %, 6 % and 4 % for the three depths (0-30cm, 30-60cm and 60-90cm). Detailed Comparison analysis across the soil depths using Analysis of Variance (ANOVA) showed no significant difference in the mean bulk density values at the depth 30-60cm and 60-90cm. But there was significant difference between depth 0-30cm and other lower depths at $p< 0.05$ using Least Significant Difference (LSD). Further observation of the bulk density across the depth showed that the mean bulk density values increase as the depth increased. This may be associated with the progressive decrease in soil organic matter content down the soil profile.

3.3 Moisture Content (MC)

Moisture content values between 9% and 35% were obtained at several points on the field.The mean moisture content for the field was 17.4% for the topsoil and the mean values for depths 30-60cm and 60-90cm were 18.0% and 20.0% respectively. The mean moisture content at the time of sampling was at optimum for crop s urvival.

Table 3.1 Soil Textural Classification of Ayede-Ogbese *Fadama* Land

Sampling Points	Lat.	Long.	Sand	Clay	Silt	Textural class
1	7.2603	5.3785	13.7	72	14.3	Clay
2	7.2583	5.3797	23.2	40	36.8	Clay Loam
3	7.2584	5.3783	48.2	34	17.8	Sandy Clay Loam
4	7.2598	5.3817	62	25.6	12.4	Sandy Clay Loam
5	7.2576	5.3794	49.6	29.4	21	Sandy Clay Loam
6	7.2642	5.3845	55.6	26.6	17.8	Sandy Clay Loam
7	7.2634	5.3802	53.6	31.8	14.6	Sandy Clay Loam
8	7.2632	5.3764	68.8	25	6.2	Sandy Clay Loam
9	7.2652	5.3792	63	11.2	25.8	sandy loam
10	7.2622	5.3759	59.8	18.6	21.6	sandy loam
11	7.2586	5.3771	23.8	40	36.2	Clay Loam
12	7.2586	5.381	35.4	25.4	39.2	Clay Loam
13	7.2576	5.3764	26	40.4	33.6	Clay Loam
14	7.2571	5.3761	65.2	28	6.8	Sandy Clay Loam
15	7.2566	5.3702	58.6	18.4	23	sandy loam
16	7.2543	5.378	29.8	40.2	30	Clay Loam
17	7.2569	5.3797	54.6	24.4	21	Sandy Clay Loam
18	7.2652	5.3776	53	35.2	11.8	Sandy Clay Loam
19	7.2632	5.3769	60	14.8	25.2	sandy loam
20	7.2664	5.378	55	19.6	25.4	sandy loam
21	7.2654	5.3755	17.2	59.4	23.4	Clay Loam
22	7.2666	5.3795	51.4	29.2	19.4	Sandy Clay Loam
23	7.2685	5.3774	61	25.4	13.6	Sandy Clay Loam
24	7.2675	5.3802	54.4	34.6	11	Sandy Clay Loam
25	7.2547	5.3792	60.8	27	12.2	Sandy Clay Loam
26	7.2591	5.3745	29.4	40.2	30.4	Clay Loam
27	7.252	5.3798	20.6	40	39.4	Clay Loam
28	7.2515	5.3814	50.6	30.4	19	Sandy Clay Loam
29	7.2492	5.3822	57.8	30	12.2	Sandy Clay Loam
30	7.2484	5.3841	45.8	16.6	37.6	sandy loam
31	7.2503	5.3805	13	70	17	Clay
32	7.2475	5.3829	38	39.8	22.2	Clay Loam
33	7.2448	5.3833	22	40.4	37.6	Clay Loam
34	7.2416	5.3841	61.6	29	9.4	Sandy Clay Loam
35	7.2387	5.3865	49	32.8	18.2	Sandy Clay Loam
36	7.2341	5.386	30.8	39.2	30	Clay Loam
37	7.2314	5.3838	58	24	18	Sandy Clay Loam
38	7.237	5.3883	59	25	16	Sandy Clay Loam
39	7.2339	5.3836	64	26	10	Sandy Clay Loam
40	7.2561	5.3843	65.8	12.2	22	sandy loam
41	7.2554	5.3843	21	40	39	Clay Loam
42	7.2547	5.3858	20.9	40.1	39	Clay Loam
43	7.2526	5.3869	55	32.8	12.2	Sandy Clay Loam
44	7.2663	5.38	54	24.2	21.8	Sandy Clay Loam
45	7.2709	5.3764	52.6	15	32.4	sandy loam

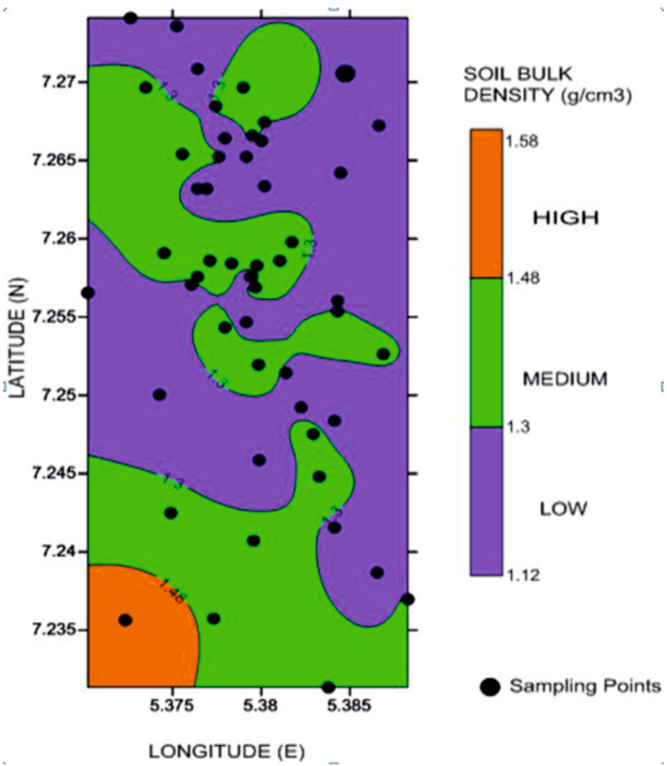

Figure 3(a): Spatial Map for the Soil Bulk Density Distribution of Ayede-Ogbese *Fadama* Area

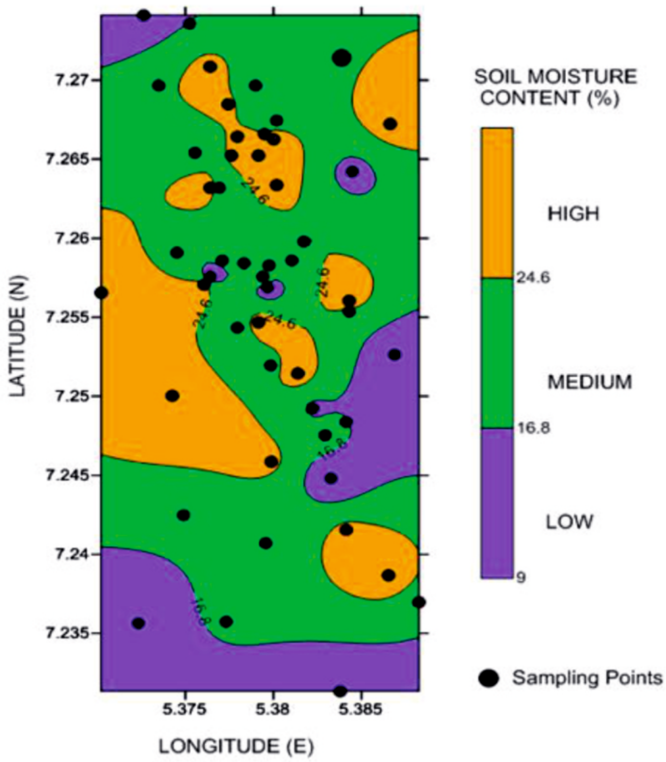

Figure 3(b): Spatial Map for the Soil Bulk Density Distribution of Ayede-Ogbese *Fadama* Area

ÇĂďů 3.2: Descriptive Statistics for the Bulk Density at various soil depths

5 ś (cm)	Mean (g/cm^3)	Minimum (g/cm^3)	Maximum (g/cm^3)	Standard Deviation	Coefficient of Variation
0-30	1.30	1.11	1.58	0.10	0.08
30-60	1.39	1.25	1.55	0.08	0.06
60-90	1.42	1.29	1.52	0.06	0.04

Table 3.3: Descriptive Statistics for the Soil Moisture Content at various soil depths

Depth (cm)	Mean (%)	Minimum (%)	Maximum (%)	Standard Deviation	Coefficient of Variation
0-30	17.4	6.4	30.5	7.10	0.41
30-60	18.0	6.7	31.6	7.35	0.41
60-90	20.0	7.4	35.1	8.17	0.41

According to Minasny et al. (2007), moisture content below 4% usually results in moisture stress for plants while moisture content above 40% result in root decay as a result of oxygen deficiency within the soil matrix. The relevance of irrigation therefore comes within this limit of moisture range.

3.4 Water Holding Capacity (WHC)

This trend of Soil Water Holding Distribution of Ayede-Ogbese Fadama Area as shown in figure 5 could be attributed to high proportion of sand content within the soil particle at this location. This phenomenon was due to low capacity of sand to retain water soil matrix. In summary, the mean value of water holding capacity for the 60-90cm depth was 31.1% while the minimum and maximum values were 21.8% and 46.3% respectively. These values were also considered suitable for crop production (Franzmeier et al., 1995). Close observation of the WHC trend across the soil depth showed that the value increased with the depth.

3.5 Soil Total Porosity

The spatial pattern of variation in the soil total porosity is related to the spatial pattern of the bulk density (Medredev, 1998). The soil total porosity and bulk density showed an inverse

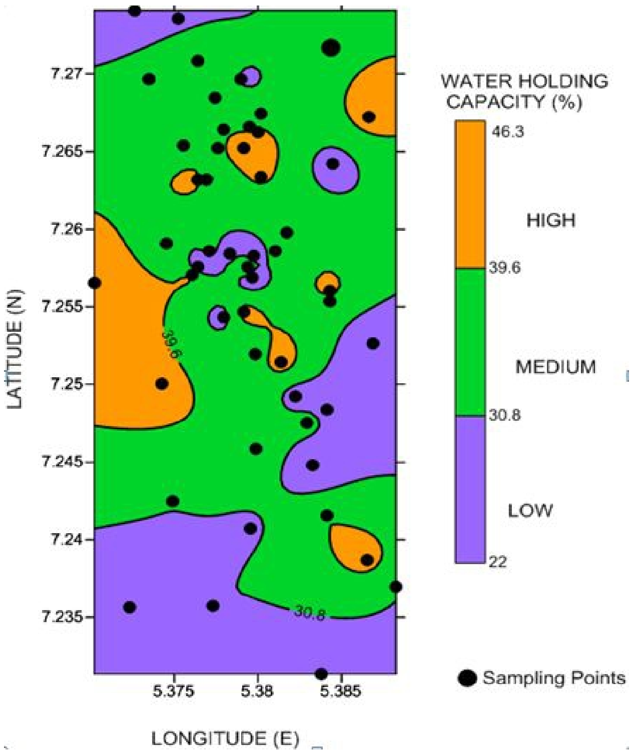

Figure 4: Spatial Map for the Soil Water Holding Distribution of Ayede-Ogbese Fadama Area

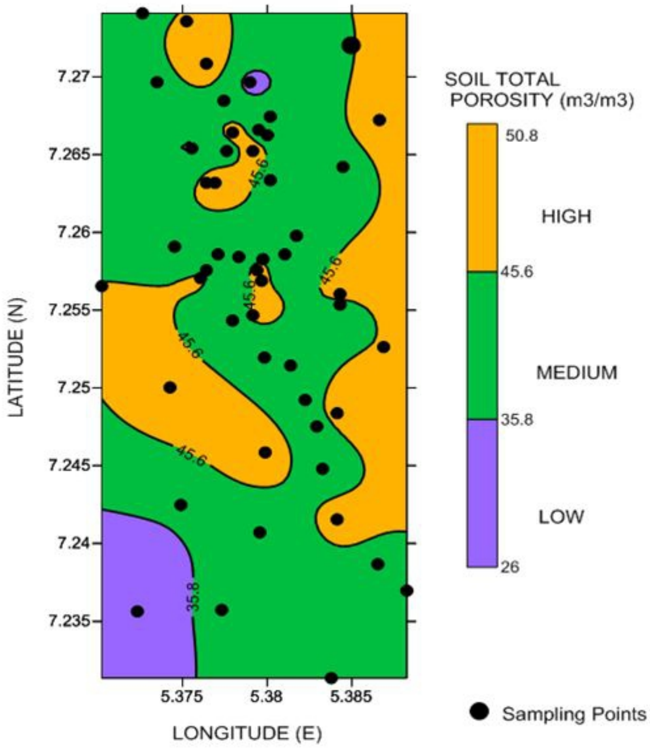

Figure 3.4: Spatial Map for the Soil Total Porosity Distribution of Ayede-Ogbese Fadama lands

Table 3.5: Descriptive Statistics for the Soil Total Porosity at various soil depths

Depth (cm)	Mean (%)	Minimum (%)	Maximum (%)	Standard Deviation	Coefficient of Variation
0-30	43.4	26.6	54.1	5.40	0.12
30-60	41.6	32.5	49.6	4.72	0.11
60-90	40.1	29.4	47.6	3.73	0.09

Table 3.6: Descriptive Statistics for the Soil Hydraulic Conductivity at various soil depths

Depth (cm)	Min (cm/hr)	Maximum (cm/hr)	Mean (cm/hr)	Standard Deviation	Coefficient of variation
0-30	0.04	0.48	0.26	0.13	0.5
30-60	0.03	0.34	0.18	0.09	0.5
60-90	0.02	0.26	0.14	0.07	0.5

relationship at $P < 0.01$ $r = -0.72$. This explains the reasons for high porosity values in locations where the bulk density is low. This can be linked with the spatial variation of organic matter content. Organic matter content played significant role in percentages of soil pores. The more the organic matter contents the lower the bulk density value and the more the soil total porosity values (FAO, 1979).

Most of the porosity values fell within the optimum level for crop production. According to Brady (1990), soil porosity is very crucial for root development and also for effective soil nutrient dynamics.

3.6 Soil Hydraulic Conductivity. (SHC)

Spatial trends of the Soil hydraulic conductivity (SHC) are as shown in Figure 3.6. It was noted that high proportion of sand content was prevalent within the high SHC locations which implies that particle size greatly influence movement of water through the soil profile (Herbst, et al., 2006)

3.7 Soil Organic Matter. (SOM)

The spatial trend of organic matter content shown in Figure 3.7 indicated that distribution varied from one location to another.

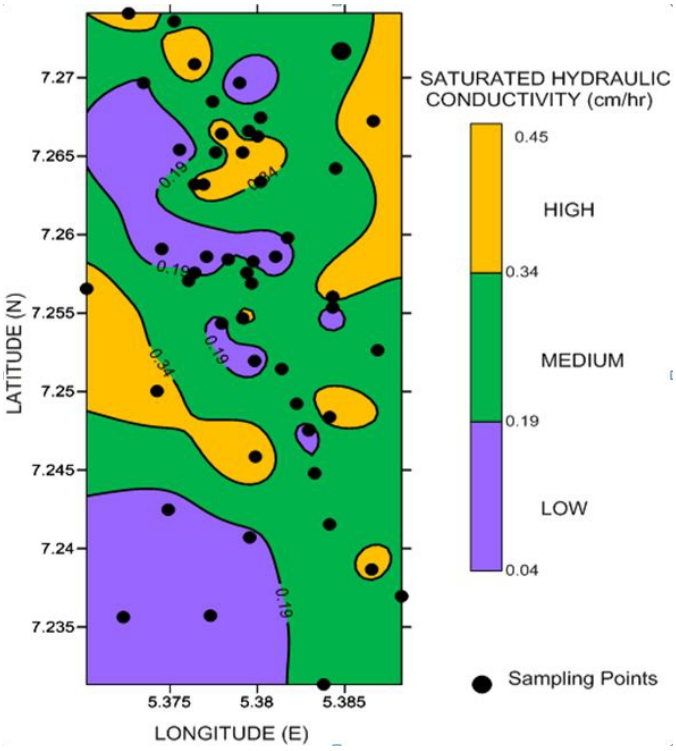

Figure 6.: Spatial Map for the Hydraulic Conductivity Distribution of Ayede-Ogbese Fadama lands

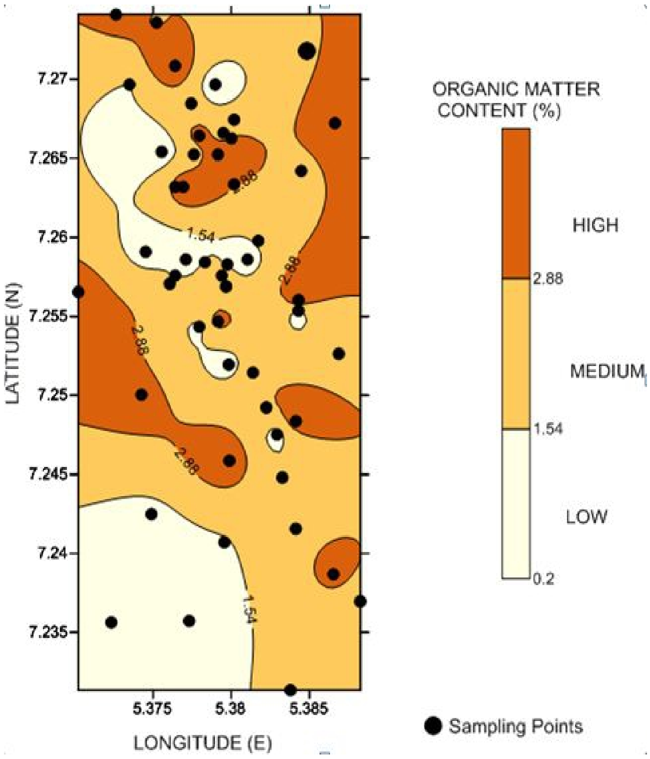

Figure 7: : Spatial Map for Soil Organic Matter Content Distribution of Ayede-Ogbese Fadama lands.

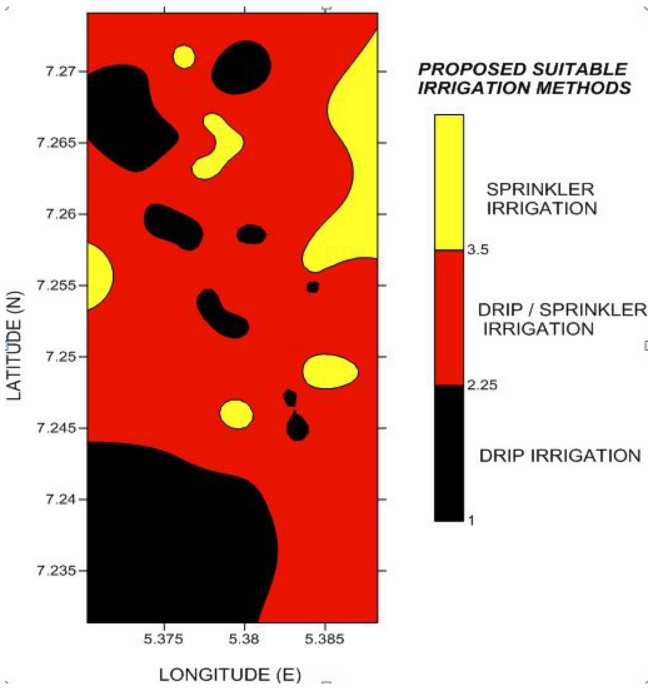

Figure 8: Spatial Map for the Proposed Suitable Irrigation Methods Ayede-Ogbese Fadama Area

The spatial distribution of organic matter content is associated with bulk density distribution within the field and similarly, it does relate with spatial distribution of soil organic carbon content (Shein and Mizury, 1998).

Descriptive statistic results of the spatial distribution in Table 4.10 showed the mean soil organic matter content for the topsoil level as 2.3 %. The minimum and maximum SOM were 0.3% and 5.37%, respectively At the depth 30-60cm and 60-90cm the mean values of the organic matter content were 0.8% and 0.5% respectively. This implies that organic matter content values are within the optimum level for crop production (Rich and Von, 2010).

3.8: Type of Irrigation System Suitable for the Study Area

Based on the spatial variation of the soil physical properties and their response to soil water conductivity potentials, the suitable irrigation system for optimum crop production varied. This was considered as a major determinant in the case of the study area presented in Figure 8 Drip irrigation is considered suitable for soils occupying the south western part and some portions of the north western part of the study area due to the prevalently low soil hydraulic conductivity. The dominant soil textural classes occupying this section of the field were clay and clay loam. Soils having low hydraulic conductivities allow serious runoff generation where irrigation methods with higher water application intensity are applied. Similarly, micro sprinkler irrigation is considered suitable in the north east and some portion of central part of the field due to the higher hydraulic conductivity of the soils within the coordinates.

The dominant soils found in these sections of the field ranged within the sandy loam textural class. However, the study area is largely suitable for either drip or sprinkler system because of the moderate hydraulic conductivity property of the soils prevalent in this area. The soil of which dominant textural class was sandy-clay

Table 3.7: Descriptive Statistics for the Soil Organic Matter Content at various soil depths

Depth (cm)	Mean (%)	Minimum (%)	Maximum (%)	Standard Deviation	Coefficient of Variation
0-30	2.3	0.3	5.3	1.17	0.51
30-.60	0.8	0.1	1.6	0.44	0.52
.60-90	0.5	0.1	0.6	0.13	0.40

-loam thus affirms the suitability of micro sprinklers as the most appropriate irrigation type for the study area.

4. Conclusion

An investigation of soil properties of Fadama lands of Ayede-Ogbese River in Ondo State, South western, Nigeria was carried out. The mean values of the physical properties investigated were: 1.30g/cm3 for the bulk density, 2.35 g/cm3 for particle density and the water holding capacity was 25 %. Furthermore, the mean values for porosity was 34 41 %, soil hydraulic conductivity of 0.04 cm/hr and organic matter content of 0.8 %. The numerical values obtained for these soil physical properties were within the optimum values for soil water movement, distribution within the soil matrix, root development and crop growth. The physical properties directly influence soil water infiltration and water storability.

More importantly, the findings had shown that the soil physical properties varied spatially from one coordinate to another and was responsible for variation in soil water and organic matter within the study area. Given consideration to optimum allocation of resources, due consideration to any of these physical properties or their combinations had provided reliable information for the selection of appropriate irrigation methods for the area.

The dominant textural class in the study area of Ayede-Ogbese Fadama lands is sandy clay loam and consequently, the recommended irrigation method is drip or/and sprinkler system.

References

Abou, Z. M. (2000). Egypt water resources management and polices. Al-Mohandseen Magazine, pp.528-535

Alatise M.O. (2004) a. Evaluation of Inputs for Investment in the Fadama Scheme to Boost Crop Production in Ondo State. A paper presented to the Annual Conference of the Nigerian Institution of Agricultural Engineers held between 22th and 26th November, at Kwara Hotels Limited, Ilorin, Kwara State, pp. 12 - 45

Alatise M.O. (2004) b. Growth; Yield and Water use Pattern of Maize under variable Limited Water Supply. Journal of Applied Science, Engineering and Technology 4(1):3-6

Arvidson, J. (2001). Subsoil compaction caused by heavy sugerbeet harvesters in Southern Sweden. Soil physical properties and crop yield in six field experiments. Soil Tillage Research. 7 (4): 32- 41

Blake, G.R. and Hartge, K.H. (1986). Bulk density in: A. Klute (Ed.). Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. 2nd.Ed. Agronomy No. 9 (part 1). ASA9 SSSA. Madison, Wisconsin, USA, pp 363-375.

Brady, N.C. (1990): The Nature and Properties of Soils. Macmillan Publishing Company, NY, pp. 89 – 99.

Brady, N.C. and Weil, R.R., (1999).The Nature and Properties of Soils 12th Edition Macmillan Publishing Company, pp. 146 – 174

FAO. (1979). Soil Survey investigation for irrigation soils. New York: John Wiley and sons Inc.

FAO/IIASA, (2008). “Harmonized World Soil Database” version 1.0, FAO, Rome, Italy & ASA, Laxenburg, Austria

Franzmeier, D.P., Lemme G.D. and Miles R.J. (1995): Organic Carbon in Soils of North Central United States Soil Science Society America Journal. 49: 702-708.

Herbst, M., Diekkruger, B. and Vanderborght, J. (2006): Numerical experiments on the sensitivity of runoff generation to the spatial variation of soil hydraulic properties. Journal. Hydrology, 326, 43-58.

Jagtab, S.S and Alabi, R.T. (1997). Reliability of daily, weekly and monthly grass evaporation using hourly estimates by Penman method in three agro-ecological zones of West Africa Nigeria, Management Journal. 2(1): 59-68

Medredev, T.H. (1998): Soil Aggregate Distribution and Soil Porosity. Harry Gray, pp.32.

Minasny, B. and McBratney, A.B. (2007): Estimating the Water Retention Shape Parameter from Sand and Clay Content. Soil Science Society of America Journal, 71, 1105-1110.

Rich, K. and Von, I. (2010) Utah State University, USA, Extension and Agriculture Department: Guidelines for Soil Quality, pp. 60

Shein and Mizury, (1998): Soil Physical Properties 5th Ed., Butterworld Publications, London, pp 53- 60.

Wardrop Engineering Incorporated (1992). Kwara State Agricultural Development Programme, Federal Agricultural Coordinating Unit. Notes on training sessions. Fadama Field Training Programme, pp. 2 - 4.

Zhang, R. (1997). “Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer.”Soil Sci. Soc. Am. J. 61: 1024-1030.