DELINEATION OF MANAGEMENT ZONES OF IRRIGATION SCHEMES IN NIGERIA BASED ON SELECTED SOIL PROPERTIES
#9517

Adesina A Wahab[1], Emeka H Ahamefule[1], Olajide J Olaniyan[2]
[1]Kwara State University, Malete, Nigeria, [2]University University of Ilorin, Keffi, Nigeria
e-mail: adesina.wahab@kwasu.edu.ng, olaniyan.jo@unilorin.edu.ng

ABSTRACT

Effective field management is required to maximize economic returns and environmental control and soil and crop management. This study was conducted to delineate the management zones (MZ) of Oke-Oyi and Eiyenkorin Irrigation Schemes (EOIS) based on selected soil properties to aid efficient water and fertilizers use and enhance productivity. Soil samples were taken at geo-referenced grid-sampling points. Total soil samples collected for each location at 0 – 20 cm and 20 – 40 cm depths were Sixty-two which were analyzed for pH, particle size distribution, and clay ratio estimate (CR). Total soil core samples (0 – 15 cm) collected were 31 in each location to determine soil bulk density (BD), saturated hydraulic conductivity (K_S), and soil total porosity (TP). Variability of measured clay content (%), BD (g/cm^3), K_S (mm/hr), and TP (%) were analyzed using Paleontological statistical software (PAST 3.14) and their maps produced using ArcGIS 10.5 tools. Management zone delineation was performed based on highly associated data using Management zone analyst software (MZA 1.0). The results revealed that there was a high correlation between the clay content measured and other measured and estimated soil properties – sand contents, BD, SHC, TP, and CR in EOIS. This source of the association was computed for MZs delineation of EIOS. The optimum numbers of MZs for EIOS were three and six (Eiyenkorin and Oke-Oyi irrigation scheme respectively). Water and nutrient transmission soil properties can be combined to give specific management zones based on their codetermined correlation.

Keywords: soil properties, irrigated fields, Management Zones, clay ratio

INTRODUCTION

Water and soil which are some of the major components of Irrigation Agriculture, do not only play an essential role in agricultural practices but specifically in sustainable management, and their important environmental effects on farming are related to their availability and quality. As such rainfall, a major source of water for agriculture which had tagged farming activities in major parts of Sub-Sahara Africa (SSA) as rain-fed, uniquely enriched soil moisture levels. However, the world is undergoing climate change (Middleton, 1997) and consequences of such changes by implication are increased in moisture deficit particularly in semi-arid and even the more humid areas (Gbadegesin and Oriola, 2004). The need for irrigation becomes more critical given several factors which include an increase in population, management of scarce resources like good planting materials, the knowledge of distribution, and variability in the soil. It also impacts the yearning of governments to reassure food security and improve rural welfare despite climate change effects and goal two of the sustainable development goals which is Zero hunger (UNDP, 2015).

According to FAO (1987) working document on the "Need and Justification of Irrigation Development in Nigeria" which classified the available irrigable land in the country into shorter (2.00 million hectares) that is irrigable lands within 0 – 1 km to the source of the irrigation water: meaning water transport distances were limited to those within one agro-ecological zone while longer (3.73 million hectares) transport irrigable lands, on the other hand, referred to land further away from the water source (more than 500 km) which means irrigation water may be transported from one agro-ecological zone to another. Although, the potentials calculated were for the levels of inputs, namely, low level of inputs, intermediate level of input, and high level of input this implies that Nigeria has substantial resources for both rain-fed and irrigable land.

However, the FAO report (2003) listed Nigeria among nations that are technically unable to meet their food needs from rain-fed production at the low level of inputs and appear likely to remain so even at intermediate levels of inputs at some time between 2000 and 2025. This further emphasizes that Nigeria cannot depend on rain-fed agriculture and expect to feed its high population except it employs in an irrigation system. Though she has established twelve (12) river basin development authorities charged with the responsibilities of developing water resources for irrigation agriculture purposes food shortage persists due to an increase in population and poor utilization of developed irrigated fields. Among the factors attributed to poor utilization of the irrigation facilities in Nigeria according to Fagbamiye (2009) is a lack of coherent irrigation subsector development policy and strategy, inadequate funding, inadequate farm support services, high capital, and operating costs, and insufficient attention to management systems. Therefore, special attention to the irrigated fields' management is required, mainly about effective soil management.

Henrique and Luis (2016) opined that knowledge of the spatial variability of soil physical and hydraulic properties influence the understanding of soil water dynamics to improve irrigated field management. In SSA, research has shown that despite the productive potential of irrigated fields, characteristics such as the uneven distribution of rainfall, high rates of evaporation, and frequently shallow and sandy soils increases the risk of soil compaction and salt accumulation (Montenegro and Montenegro, 2006). A study on an irrigated field in Nigeria which focused on the evaluation of irrigation farming at Oke-Oyi, Kwara state was therefore conducted by Gbadegesin and Oriola, (2004) who reported that the soil of the irrigation scheme was sandy and fertility status is low to adequately support sustainable maize production.

Ortega *et al*., (2007); however, reported that the improved irrigated field management is achievable by site-specific management application of crop inputs such as plant nutrients, seeds, pesticides, water, and tillage through the identification of management zones (MZ). Identification of MZ defined by field boundaries do not only aid management practices but prompt adequate planning for present and future land use thereby reducing food insecurity. This leads to reduced input costs, minimal adverse environmental effects, and improved crop yield and quality (Gemtos *et al*., 2011).

Generally, the management of soil physical attributes on a site-specific basis as described by Peralta *et al*., (2015) is an attractive and intuitive approach for increasing the input efficiency of agricultural systems by adjusting fertilizer and water rates based on the soil characteristics. Thus, the concept of management zones can be introduced to irrigation field management, which is sub-regions of a crop field that may differ in factors such as soil type, topography, water, or nutrient availability (Bullock *et al*., 2009). Valente *et al*., (2012) also submitted that management zones should be defined by evaluating more than one soil property. Delineating management zones entail the study of various soil properties (Henrique and Luis 2016) to derive the economical and functional viability of the Irrigation field. Therefore, delineating water management zones based on soil attributes can be an important technique to optimize the use of irrigated water and fertilizers in irrigated agricultural fields. The aim of this study was therefore to delineate management zones of Oke-Oyi and Eiyenkorin irrigation schemes using management zone analysis software (MZA) 1.0 and production of a map of the various management units based on the selected soil properties; this is to aid efficient use of water and fertilizers in those fields and enhance adequate productivity.

MATERIALS AND METHODS

Sites description

The study sites were Oke-Oyi and Eiyenkorin Irrigation schemes under Lower Niger River Basin Development Authority, Ilorin Kwara State, Nigeria. These areas lie approximately between longitudes 4^0 43’ 49” and 4^0 45’ 23” East of the Greenwich Meridian; Latitude 8^0 36’59” and 8^0 37’ 20” North of the equator (Oke-Oyi Irrigation scheme) and longitude 4^0 26’ 0” and 4^0 26’ 10” East of the Greenwich Meridian; Latitude 8^0 23’48” and 8^0 23’16” North of the equator (Eiyenkorin Irrigation scheme). Their elevations are 383 m and 307 m above sea level respectively. The total land area of the Oke-Oyi Irrigation scheme is 250 ha (Gbadegesin and Oriola, 2004) while that of the Eiyenkorin Irrigation scheme is 150 ha.

Generally, the two locations have two main seasons: dry and wet season with an intervening co-harmattan period usually experienced from December to January. The natural vegetation of these two locations consists of forest and wooded savannah with annual rainfall which ranges from 1000 – 1500 mm while the maximum average temperature ranges between 30 and 35 ^{0}C (Ogunleye and Oyediji, 2012).

Source and techniques of data collection
Soil sampling and analysis

Soil samples were taken at 7 × 6 m geo-referenced grid-sampling points in each of the two fields. The geo-referenced grid sampling points were determined using ArcGIS 10.5 tools. The soil sampling activities were carried out at the beginning of cropping seasoning in the two Irrigation schemes (May/June). One representative sample was collected at each grid and geo-referenced using a global positioning system (GPS). The satellite views of the areas sampled were presented in Plate 1- Oke Oyi and 2- Eiyenkorin irrigation project stations respectively with their coordinate points (Google Earth, 2016). The variability in selected soil physical properties of each point was determined by taking undisturbed soil core samples at depth of 0 to 15 cm in each point using a core sampler. Saturated hydraulic conductivity (K_s), total porosity (TP), and soil bulk density were determined from each sample using the conversational methods as described by Flint and Flint (2002).

Also, soil samples of each point were taken from the 0 to 20 cm and 20 to 40 cm layers using soil auger which gave 31 soil samples each from 0 – 20 cm and 20 – 40cm. The total soil samples were 62 at each location. On each sample, particle size distribution was determined by the Hydrometer method (Gee and Or, 2002). Soil pH was determined in water using a 1:1 soil – solution ratio with a pH meter.

Clay ratio, one of the indices for soil erodibility was determined as indicated below:

Clay ratio = (% sand + % silt) / % clay) according to Oshunsanya *et al.*, (2012)

Statistical analysis

Measured variables were analyzed using descriptive statistical methods to obtain values for the mean, standard deviation (SD), minimum, maximum, coefficient of variation, skewness, and correlations analysis in Paleontological statistics software package (PAST 3.14). The statistical package was used to express the association within and among measured and estimated selected soil physical data before delineating management zones. Selected soil physical properties were used in delineation based on their role in determining nutrients and water availability for crop and plant growth as well as acting as a conduit between the soil surface and groundwater (Marcos *et al*., 2015). ArcGIS 10.5 software was employed to produce spatial distribution maps of selected soil properties (Hou-Long *et al*., 2012).

Management zones were delineated in Management Zone Analyst software 1.0 (MZA) by using the most correlated soil properties values. The management zones delineation using Management Zone Analyst 1.0 (MZA) (Fridgen et al. 2004), analysis data, and construct models to find the relationship among different variables without prior experience aided by a powerful unsupervised method characterized by Fuzzy clustering. It can be used to divide a field into different groups with multiple attributes, which can reduce distortion by outliers (Brown 1988). At the same time, fuzzy clustering used a weighting exponent to control the degree to which membership sharing occurs between classes (Bezdek 1981). The technique of fuzzy clustering has been used to classify soil, landscape data (Burrough et al. 1992; Reyniers et al. 2006) and yield data (Lark 1998). Unsupervised clustering algorithms have been proposed for delineating MZs from yield monitor data (Lark and Stafford 1997; Stafford *et al*. 1998).

The fuzzy performance index (FPI) (Hou-Long *et al*., 2012) and normalized classification entropy (NCE) (Boydell and McBratney 1999) were used to determine the optimal number of clusters. The FPI is a measure of the degree to which different classes share membership (Fridgen *et al*., 2004). Values approaching 0 indicate distinct classes with little membership sharing, while values near 1 indicate non-distinct classes with a large degree of membership sharing.

The value of NCE was then calculated for each classification (Lark, 2001). FPI and NCE were calculated according to Fridgen *et al*. (2004) using MZA 1.0 software.

The best classification was determined when each index is at a maximum, representing the least membership sharing (FPI) and the greatest amount of organization (NCE) because of the clustering process (Fridgen *et al*. 2004).

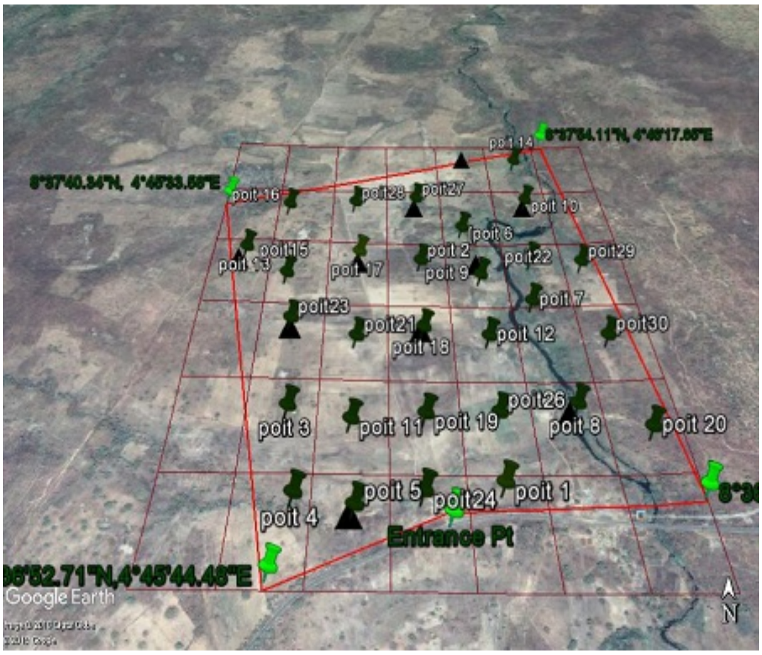

Plate 1. Satellite view of Cultivated Area under Oke-oyi Irrigation Project Station-Lower Niger River Basin Development Authority

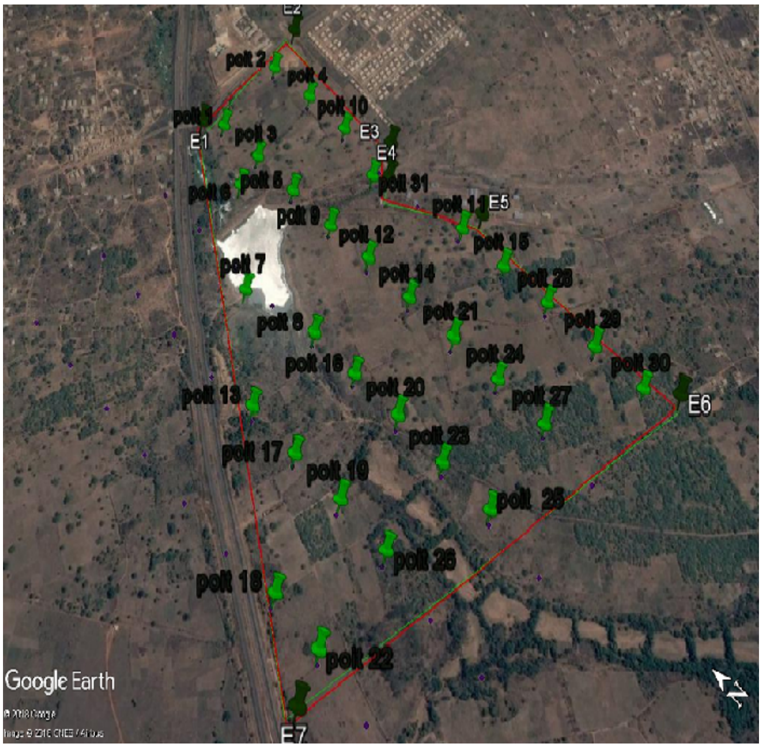

Plate 2. Satellite view of Cultivated Area under Eiyenkorin Irrigation Project Station- Lower Niger River Basin Development Authority

RESULTS

Descriptive statistics of soil variables at 0 – 20 cm and 20 – 40 cm depths of the studied areas were reported in Table 1 and 2. It was evident that the two sites, Eiyenkorin and Oke-Oyi Irrigation schemes (EIOS) soils (0 – 20 cm and 20 – 40 cm soil depth) are slightly acidic, with a mean pH value of 5.89; 6.05; 6.41, and 6.30 respectively. The highest clay ratio (CR) - 47.24 %, and TP – 24.10 % were recorded in the Oke-Oyi Irrigation scheme when compared to the Eiyenkorin Irrigation scheme CR percent of 46.34 and 16.34 at depth of 0 – 20 cm (Table 1). At 20 – 40 cm, the Eiyenkorin Irrigation scheme had the highest sand content, K_S and TP. Most of the soil properties were moderately skewed except the K_S in the Eiyenkorin field at 0 – 20 cm (Table 1) which was indicated by 0.00 skewed value, the meaning is normally distributed at that depth. The distribution of all the variables was only slightly skewed (Skewness $-1 \leq X \leq 1$).

The results also revealed that the distribution of sand content of the EOIS ranged from 76 % to 92 % with a mean value of 84.40 % and 76.82 % (Table 1); 84.6 % and 76.9 % (Table 2) respectively. This indicates that the soil of EIOS is coarse-textured soils. The mean silt and clay content was however higher in the Oke-Oyi Irrigation scheme (8.61% and 14.5%) compared to that of Eiyenkorin (4.50 % and 11.00 %). The lowest coefficient of variation (CoV) was recorded for the BD variable with a mean value of 1.47 g/cm^3 and 1.49 g/cm^3 respectively. The range of BD for the EIOS was 1.42 g/cm^3 to 1.7 g/cm^3. The highest and the lowest SD value was recorded at Oke-Oyi Irrigation schemes (21.17 and 0.02) with K_S and BD variables respectively. The skewness of all samples from 20 – 40 cm ranged from - 0.62 to 2.12. This implies that most of the variables had Skewness between -1 and 2 which implies that most of the results are moderately skewed while few were highly skewed. Based on CoV values, BD and TP were classified as low (CoV < 10%) and their mean varied from 1.46 to 1.49 g cm^{-3} BD; 43.60% to 44.60%TP (Table 1) and 1.47 g cm^{-3} to 1.49 g cm^{-3}BD; 43.60% to 44.15%TP (Table 2) which are characteristics of sandy soils (Saxton *et al*., 2006).

Correlation analysis of almost all the selected soil properties at 0 – 20 cm depth of the Eiyenkorin Irrigation scheme was significantly correlated (Table 3). The clay content of the fields was highly positively correlated with sand content (0.638) and BD (0.493), while it was highly negatively correlated with K_S (- 0.948), TP (- 0.493), and CR (- 0.947).

Soil pH was not significantly correlated with the rest of the variables considered. BD was negatively correlated to TP ($P < 0.01$) and it had the highest correlation observed.

The correlation coefficient of CR and TP was consistently negative at $p<0.01$ in all correlation analysis tables presented. This implies that a unit increase in CR value will result in a unit decrease in TP. Also, a significant increase in clay content will cause a significant decrease in BD as shown in all the correlation analysis shown.

Similar trends were also observed in Tables 4, 5, and 6 where correlation analysis of selected soil properties at 20 – 40 cm depth of Eiyenkorin Irrigation schemes, 0 – 20 cm, and 20 – 40 cm for Oke-Oyi Irrigation scheme as presented respectively.

Spatial variability maps of selected soil properties- textural class, clay content, BD, $K_{S,}$ and TP for EOIS were presented in Fig. 3 (A, B, C, and D) and 4 (A, B, C, and D) respectively. The distribution of soil types in the Eiyenkorin Irrigation scheme as determined were Sandy, Sandy Loam, and Loamy sand textural classes. While the most common textural class in the Oke-Oyi Irrigation scheme is loamy sand (LS), sandy clay loam (SCL), and Sandy loam (SL), and the least common is Sandy soils (S) as well as in the Eiyenkorin Irrigation field. The clay content and K_s for the EOIS varied with five unique values classes whereas BD and TP showed three distinctive classes. The spatial distribution of the most or highly spread ranged of the soil properties was indicated by brown color on each of the maps while the least was often indicated by either white or green colors. The range of BD for Eiyenkorin was 1.42 g cm^{-3} to 1.51 g cm^{-3} while that of Oke-Oyi ranged from 1.41 g cm^{-3} to 1.93 g cm^{-3}. There is a close similarity in the variation observed in TP for EOIS as both values ranged from 42 % to 46.21 % (Eiyenkorin) and 42 % to 46.59 % (Oke-Oyi). On the other hand, wide variation was observed in K_s value for the Oke-Oyi Irrigation scheme which ranged from 5.9 mm/hr to 121.34 mm/hr whereas the variation in K_s in Eiyenkorin Irrigation scheme as observed was close, ranging from 35.48 mm/hr to 99.11 mm/hr. However, the clay content for each scheme ranged from 6.00 % to 16.00 % (Eiyenkorin) and 4.02 % to 30.15 % (Oke-Oyi).

Clay contents measured data for EOIS were tabulated and regarded as the input data of MZA software. The fuzziness performance index (FPI) and normalized classification entropy (NCE) when the clustering number was 2, 3, 4, 5, and 6 respectively were obtained from MZA and shown in Fig. 5 (A and B). FPI and NCE achieved the smallest values while the number of management zones was 4 in Fig. 5 A and B. The classification effect was strongly best when the study area was partitioned into 3 management zones (Fig. 5A) while the classification effect was best when the study area was partitioned into 6 management zones (Fig. 5B). The management zones map was obtained from ArcGIS software with the input data of the selected soil properties values.

Fig. 5A and B shows changes in two performance indices with an increasing number of management zones using clay content data for Oke-Oyi (A) and Eiyenkorin (B) Irrigation scheme. The highest value for the management zone in A was 0.036 at the FPI when the number of zones reached 3 whereas the NCE value was highest at 0.019 at the same number of the zone. However, the highest NCE value recorded at B was 0.0028 when the number of zones reached 6 which is the same number of zones recorded at FPI (0.0021) of B.

Table 1. Descriptive statistics of selected soil variables at 0 – 20cm depth (n=31) of the study area.

Variables	Mean		SD		Minimum		Maximum		CoV		Skewness	
	E	O	E	O	E	O	E	O	E	O	E	O
pH (H_2O) 1:1	5.89	6.41	0.45	0.49	5.14	5.47	7.83	8.45	0.2	0.2	-0.22	0.62
Silt (%)	5.44	7.10	2.11	3.26	1.00	2.00	10.00	14.00	4.5	10.6	-0.18	0.49
Clay (%)	10.00	16.10	2.57	7.74	6.00	4.00	16.00	31.00	6.6	59.9	0.65	0.55
Sand (%)	84.40	76.82	2.66	9.58	80.00	62.50	91.50	90.70	7.1	91.7	0.38	-0.31
BD (g cm^{-3})	1.46	1.49	0.02	0.03	1.43	1.42	1.60	1.55	0.0	0.1	0.04	-0.70
K_S (mm/hr)	67.20	45.00	17.75	30.00	35.53	5.96	99.01	121.00	315	918.2	-0.00	0.40
TP (%)	44.60	43.60	0.91	1.10	43.68	42.15	46.34	47.24	0.8	1.12	-0.04	0.69
Clay ratio (%)	9.60	6.90	2.73	4.40	5.20	2.05	16.30	24.10	7.4	19.5	0.71	1.99

Note: E = Eiyenkorin Irrigation scheme study area; O = Oke-oyi Irrigation scheme study area; SD = standard deviation; CoV = Co-efficient of Variation; BD = Bulk density; K_S = Saturated hydraulic conductivity; TP = Total porosity

Table 2. Descriptive statistics of selected soil variables at 20 – 40cm depth (n=31) of the study area.

Variables	Mean		SD		Minimum		Maximum		CoV		Skewness	
	E	O	E	O	E	O	E	O	E	O	E	O
pH (H_2O) 1:1	6.05	6.30	0.47	0.59	5.00	5.19	7.57	7.63	0.2	0.4	-0.46	0.34
Silt (%)	4.50	8.61	2.10	6.94	0.00	0.00	9.00	28.00	4.3	48.2	-0.15	1.24
Clay (%)	11.00	14.45	2.61	6.46	6.00	6.48	16.50	38.48	6.8	41.8	-0.01	2.12
Sand (%)	84.6	76.9	0.47	10.05	80.00	47.52	90.00	89.52	8.3	101.1	0.13	-1.27
BD (g cm^{-3})	1.47	1.49	0.03	0.02	1.42	1.45	1.75	1.53	0.0	0.0	-0.62	-0.39
K_S (mm/hr)	63.10	45.41	18.12	21.17	36.00	1.48	99.50	88.39	328	448	0.36	0.04
TP (%)	44.13	43.60	1.00	0.77	42.00	42.05	47.35	45.08	1.0	0.5	0.62	0.39
Clay ratio (%)	8.70	6.99	2.64	2.94	5.00	1.60	16.30	14.43	7.0	8.7	1.16	0.88

Note: E = Eiyenkorin Irrigation scheme study area; O = Oke-Oyi Irrigation scheme study area; SD = standard deviation; CoV = Co-efficient of Variation; BD = Bulk density; K_S = Saturated hydraulic conductivity; TP = Total porosity

Table 3. Correlation analysis of selected soil properties at 0 – 20 cm depth of Eiyenkorin Irrigation schemes.

	pH (H_2O)	Silt (%)	Clay (%)	Sand (%)	BD	K_S	TP	CR
pH (H_2O)	1							
Silt (%)	0.027	1						
Clay (%)	-0.082	-0.389*	1					
Sand (%)	0.081	-0.450**	-0.638**	1				
BD	0.329	-0.113	0.493**	-0.387*	1			
K_S	0.001	0.220	-0.948**	0.730**	-0.385*	1		
TP	0.329	0.113	-0.493**	0.387*	-1.000**	0.385**	1	
CR	0.048	0.351*	-0.947**	0.630**	-0.464**	0.948**	0.464**	1

* and **Significant at the 0.05 and 0.01 probability level respectively.
Note: BD = Bulk density; SHC = Saturated hydraulic conductivity; TP = Total porosity; CR = clay ratio

Table 4. Correlation analysis of selected soil properties at 20 – 40cm depth of Eiyenkorin Irrigation schemes.

	pH (H_2O)	Silt (%)	Clay (%)	Sand (%)	BD	K_S	TP	CR
pH (H_2O)	1							
Silt (%)	0.021	1						
Clay (%)	0.084	-0.235	1					
Sand (%)	-0.074	-0.471**	-0.735**	1				
BD	-0.012	-0.206	0.611**	-0.384**	1			
K_S	-0.107	0.006	-0.947**	0.838**	-0.638**	1		
TP	0.012	0.206	-0.611**	0.384**	-1.000**	0.638**	1	
CR	-0.002	0.224	-0.956**	0.699**	-0.596**	0.931**	0.596**	1

* and **Significant at the 0.05 and 0.01 probability level respectively.
Note: BD = Bulk density; SHC = Saturated hydraulic conductivity; TP = Total porosity; CR = clay ratio

Table 5. Correlation analysis of selected soil properties at 0 – 20cm depth of Oke-Oyi Irrigation schemes.

	pH (H_2O)	Silt (%)	Clay (%)	Sand (%)	BD	K_S	TP	CR
pH (H_2O)	1							
Silt (%)	0.233	1						
Clay (%)	-0.248	0.711**	1					
Sand (%)	-0.139	0.491**	-0.956**	1				
BD	-0.103	0.406*	0.891**	-0.839**	1			
K_S	-0.101	-0.565**	-0.948**	0.942**	-0.965**	1		
TP	0.103	-0.407*	-0.891**	0.840**	-1.000**	0.965**	1	
CR	0.042	-0.403*	0.832**	0.806**	-0.940	0.943**	0.939**	1

* and **Significant at the 0.05 and 0.01 probability level respectively.
Note: BD = Bulk density; SHC = Saturated hydraulic conductivity; TP = Total porosity; CR = clay ratio

Table 6. Correlation analysis of selected soil properties at 20 – 40 cm depth of Oke-Oyi Irrigation schemes.

	pH (H_2O)	Silt (%)	Clay (%)	Sand (%)	BD	K_S	TP	CR
pH (H_2O)	1							
Silt (%)	-0.005	1						
Clay (%)	0.025	-0.182	1					
Sand (%)	-0.005	-0.780**	-0.685**	1				
BD	0.109	-0.258	0.696**	-0.235	1			
K_S	-0.023	-0.373*	-0.967**	0.813**	0.385*	1		
TP	-0.109	0.258	-0.696**	0.387*	-1.000**	0.627**	1	
CR	0.025	0.182	-1.000**	0.630**	-0.696**	0.967**	0.696**	1

* and **Significant at the 0.05 and 0.01 probability level respectively.
Note: BD = Bulk density; SHC = Saturated hydraulic conductivity; TP = Total porosity; CR = clay ratio

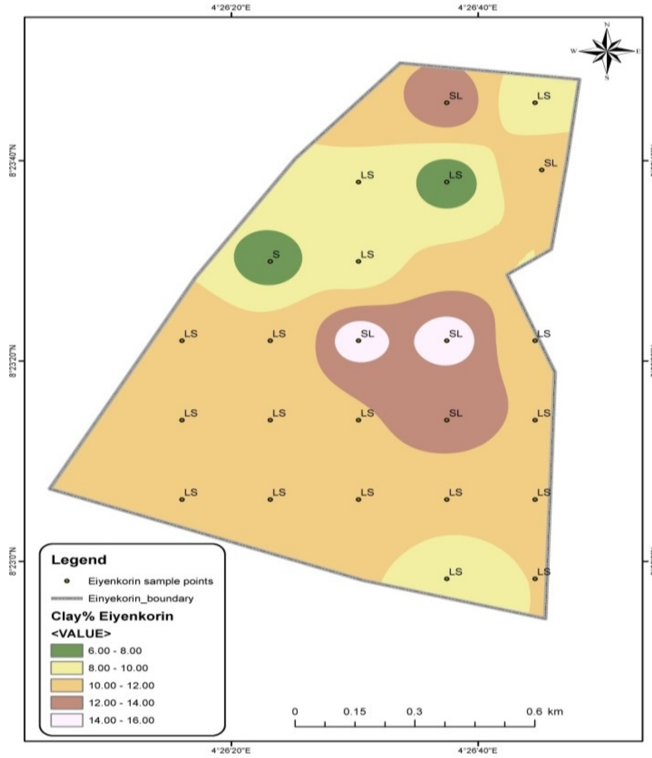

Fig. 3A. Spatial variability map of clay content for Eiyenkorin Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy.

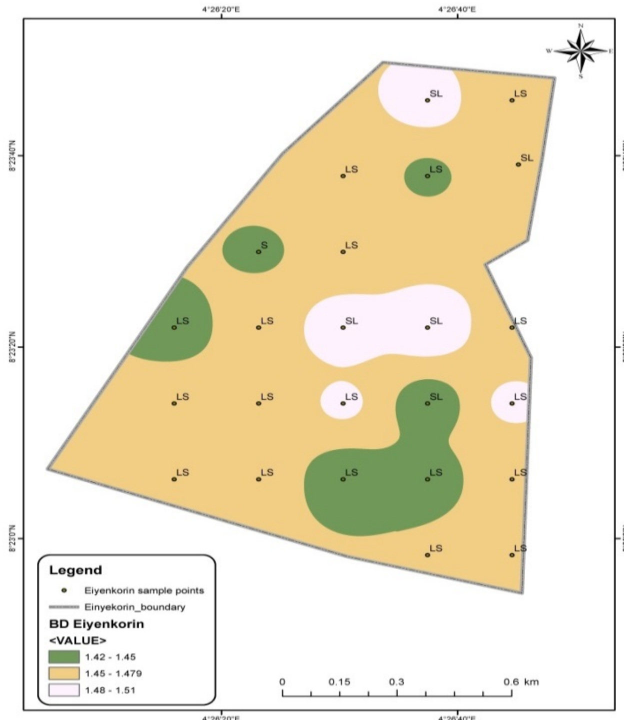

Fig. 3B. Spatial variability map of BD for Eiyenkorin Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy.

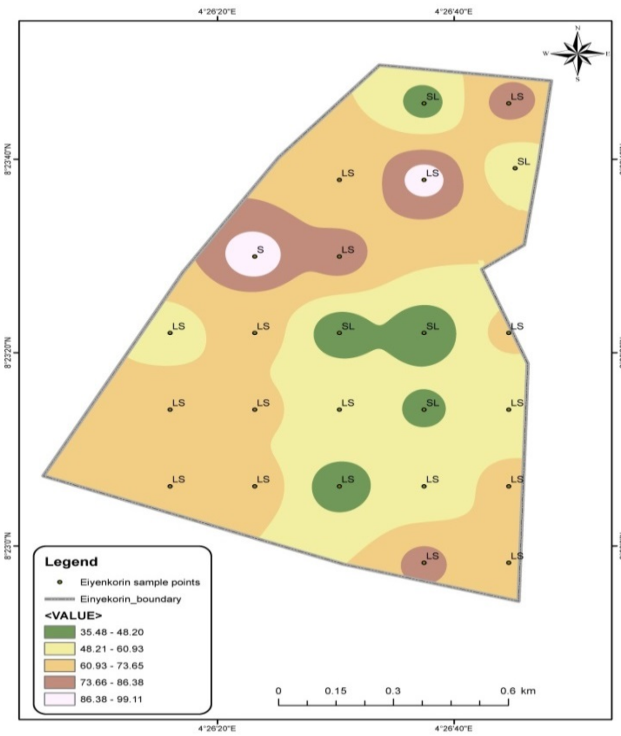

Fig. 3C. Spatial variability map of K_S for Eiyenkorin Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy.

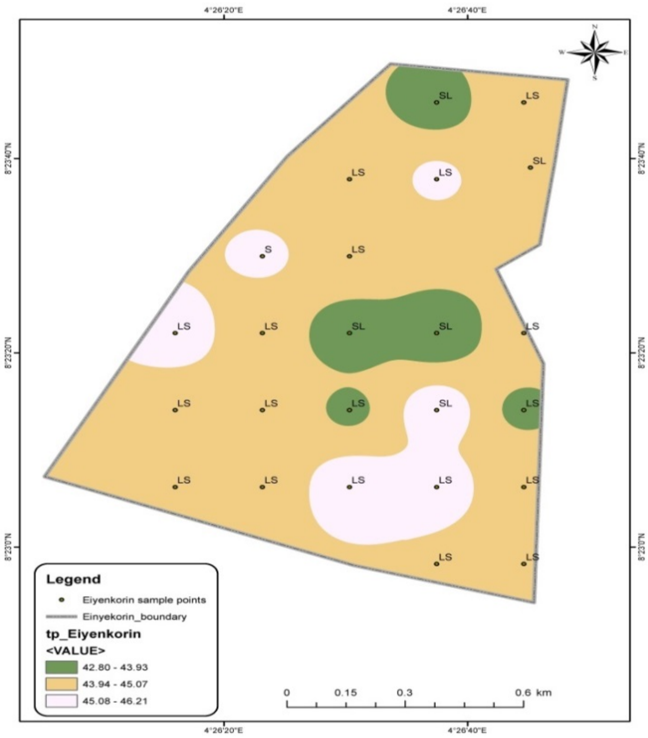

Fig. 3D. Spatial variability map of TP for Eiyenkorin Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy.

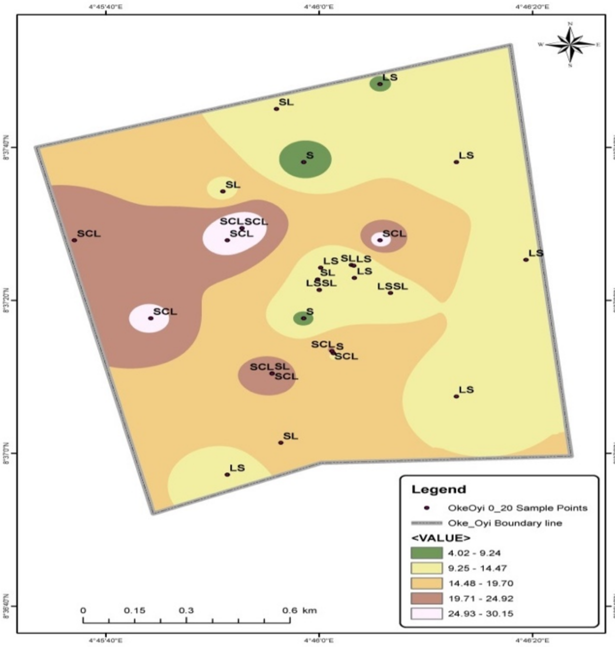

Fig. 4A. Spatial variability map of clay content for Oke-Oyi Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy; SCL = Sandy clay loam.

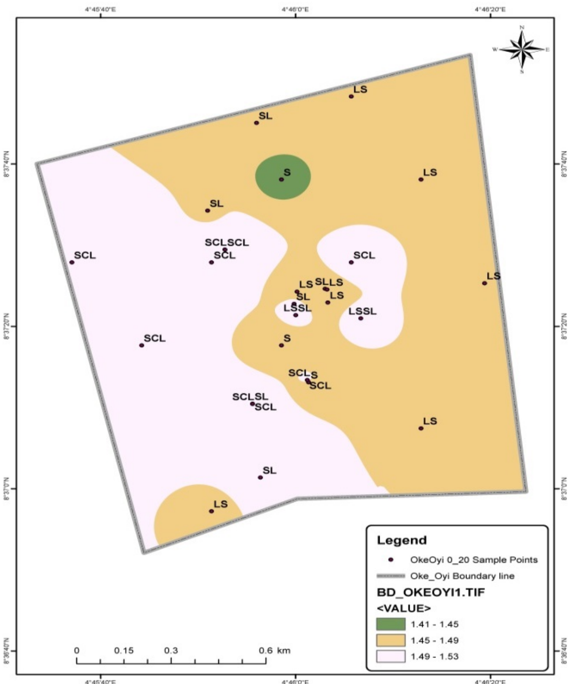

Fig. 4B. Spatial variability BD for Oke-Oyi Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy; SCL = Sandy clay loam.

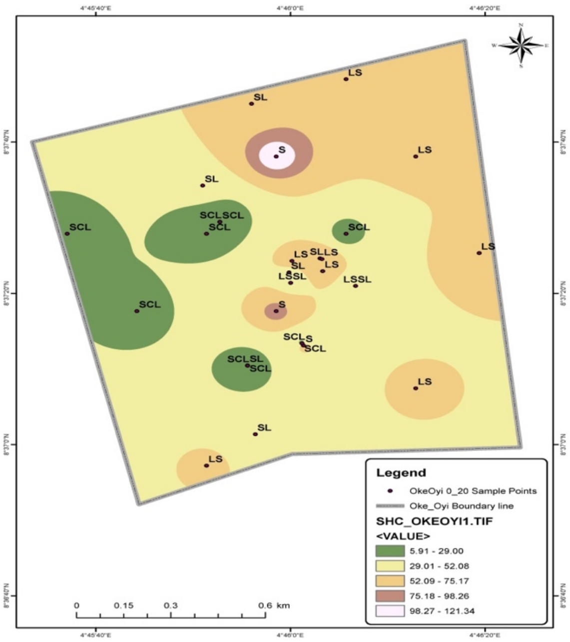

Fig. 4C. Spatial variability map of K_S for Oke-Oyi Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy; SCL = Sandy clay loam.

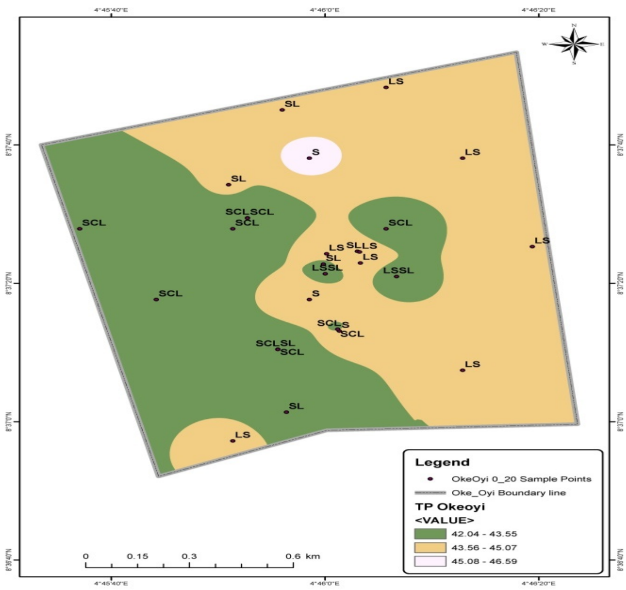

Fig. 4D. Spatial variability map of TP for Oke-Oyi Irrigation Scheme. Note: LS = Loamy sand; SL = Sandy loam; S = Sandy; SCL = Sandy clay loam.

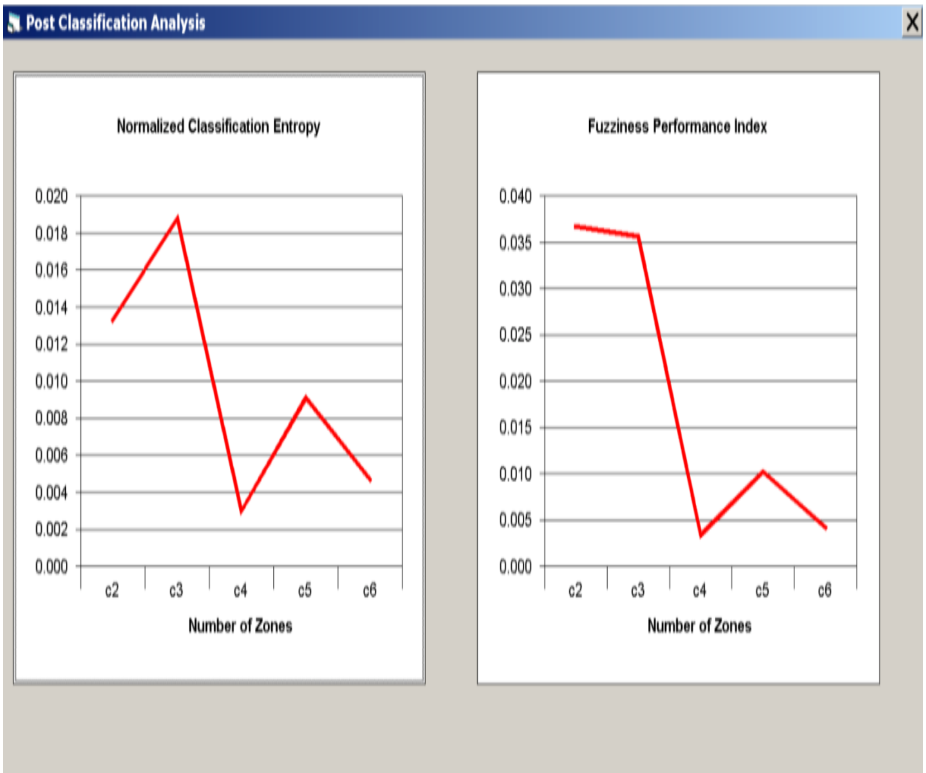

Fig. 5A. Changes in two performance indices with an increasing number of management zones using clay content data for Oke-Oyi Irrigation scheme.

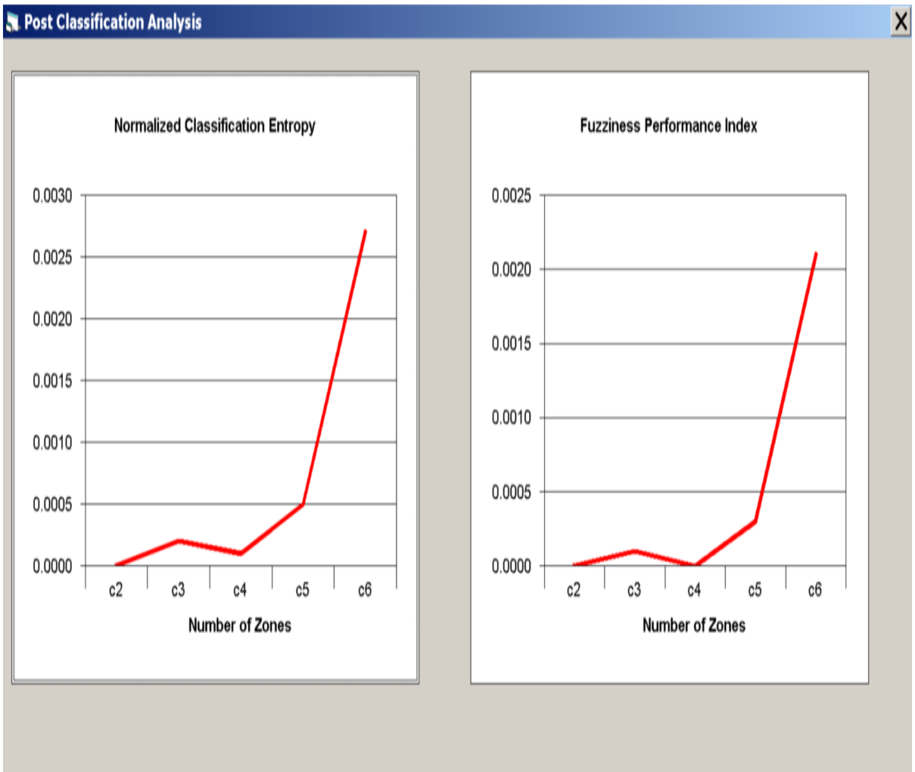

Fig. 5B. Changes in two performance indices with an increasing number of management zones using clay content data for Eiyenkorin Irrigation scheme.

DISCUSSION

Sites characteristics

Soil ph, soil bulk density, total porosity, and saturated hydraulic conductivity

The selected soil properties of the study sites (EIOS) at two different depths (0 – 20 cm and 20 – 40 cm) reflected that the soil reactions ranged from slightly acidic to slightly alkaline. This is an indication that the reaction of the soil will support most crops like maize, potatoes, okra, pepper, garden egg, cassava, and yam commonly cultivated in the area. Okalebo *et al*., (2002) reported improved plant productivity of some cereals and vegetable crops with a soil pH range from the acidic to alkaline. Since the pH in the water for all the samples irrespective of the horizons are above 5.0, thus the fields will have a direct impact on plant productivity. This find is in line with H.-L. Jiang *et al.* (2012) submission that the change in soil pH, soil bulk density, total porosity, and K_S within the specific agronomical field are often caused by frequently altered planting patterns, irregular crop growth, and different management practices, leading to a marked alteration in topsoil quality and health status over small distances.

Most of the soil properties were not moderately distributed except the K_S in the Eiyenkorin field at the topsoil level that is normally distributed. This is indicated that most of the soil properties measured were either high or low at short distances and depth which often lead to either Negative Skewness (when the tail of the left side of the distribution is longer or fatter than the tail on the right side) or Positive Skewness means when the tail on the right side of the distribution is longer or fatter. According to Young *et al.* (1999) findings, the long tails of skewed distributions imply that there are inclusions or outliers within a studied field, because of distinct change in the environmental deposition and/or the asymmetric effects of the pedogenic or hydrologic process.

The variation in soil bulk density (BD) suggested that there are regions in the study sites that BD values are higher and moderately varies both in-depth and location within EIOS but not necessarily higher than the critical interval (1.60 to 1.80 g cm^{-3}) for sandy soils as proposed by Reichert *et al*., (2003). Soil total porosity (TP) values also showed moderately high variability, indicating that plants survive water and/or air stress in most of the study fields (Reichert *et al*., 2003). Based on CoV values, the EIOS field had the low BD and TP which agrees with Saxton and Rawls, (2006) findings which they used to characteristics coarse-textured or sandy soils.

The higher variability in EIOS saturated hydraulic conductivity (K_S) affirmed the fact the field is sandy (Rodrigues *et al*., 2015). This also implies that the field will be moderately saturated, and plants will survive water and/or air stress especially during waterlogged conditions because of a heavy downpour or water application through irrigation (Oshunsanya *et al*., 2012; Rodrigues *et al*., 2015). The need for effective water and nutrient management becomes imperative as the EIOS soil characteristics required adequate management of nutrient amendments and water availability for optimum crop growth and yield as described in separate reports by Gbadegesin and Oriola (2004) and Foth (2014).

Particle size distribution

The texture of the soils was largely determined along a linear sequence of the textural class by the relative proportion of sand, silt, and clay fractions. The soil types/textural class determined in EOIS were sandy clay loam, loam sand, loam, sandy loam, and sand. The linear sequence of textural class determined could be linked to lower clay and silt fraction within EIOS irrespective of the depth of the soil. The main reason for this is due to the inherent capacity of the field because of the pedogenic process and rock constituents. Although the clay content was generally low within EIOS, the Eiyenkorin field had some of the areas with significantly higher clay fraction which explain the feasible waterlogged area within the field which the farmers classed as Fadama that they used for cultivation when dry soil had fully established. However, the EIOS soils were generally dominated by loamy sand.

Spatial distribution of selected soil properties

Generally, the maps showed the distribution of soil textural class of the study site on which the distribution of highly correlated selected soil properties was reflected thus, served as the base map for the spatial distribution of soil properties. The soil textural class range from sandy to sandy clay loam. The most distributed selected soil properties were indicated by brown color while the least was indicated by white and green color. The deduction from this is that all the selected soil properties had unique spatial variability and heterogeneous spatial distributions which often resulted in three (BD and TP) and five (K_s and clay contents) boundaries classes in the EIOS. However, it can also be deduced that less than 25 % of the Eiyenkorin field is degraded while close to 40 % of the Oke-Oyi field is degraded. This could be a link to the period of cultivation, management practices, and cropping patterns. However, there was clear evidence of adequate management practices and non-uniform cropping patterns on the EIOS. It was observed that the orientation for the tillage operation was along the slope as against the standard which is across the slope as well as inadequate cropping sequence and fertilizer application. This agrees with H.-L. Jiang *et al.* (2012) study that refilled that the determinant for the spatial correlation of soil properties is a function of the structural factors that include soil parent material, topography, fertilizer application, crop planting pattern, soil management, and water table.

This implies that the most distributed soil properties can be used as a basic range for the adequate guide to determine the rate of water and nutrient applications. This will also provide adequate support for the choice of effective management practice that will not only lead to precision agriculture but a sustainable management approach to the agronomical field.

Correlation analysis

The consistently negative correlation coefficient of CR and TP implies that a unit increase in CR value will result in an impact decrease in TP. Also, a significant increase in clay content will cause a significant impact in BD of the EIOS field. This could be attributed to the role of clay particles in soil structure, textural formation, and aggregation. Generally, extremely significant correlations were observed between sand content, SHC, TP, CR properties of EOIS ($P<1\%$) with clay content. Thus, clay content measured data for EOIS was used for delineating management zones. According to Henrique and Luis (2016), clay attribute was found to have the greatest heterogeneity in their studied area, Quartzipsamment of the Brazilian semiarid region.

Delineating management zones

The MZs for EIOS was indicated by changes in two performance indices with an increasing number of management zones using clay content data for Oke-Oyi (A) and Eiyenkorin (B) Irrigation scheme. The implication of this is that EOIS can be managed effectively with 3 and 6 distinctive MZs based on the clay content attributes that related significantly with the water and nutrient transmission (SHC) (Rockstro¨m *et al*., 2007) indices such as soil erodibility (CR) (Oshunsanya *et al*., 2012); water and air pores (TP) and soil bulk density (Rodrigues *et al*., 2015).

CONCLUSIONS

The soil in the study area was characterized by high variation and correlated soil properties like clay content, SHC, BD, TP, and CR. This resulted in the creation of 3 MZs for the Okeoyi Irrigation scheme and 6 MZs for the Eiyenkorin Irrigation scheme. This could be due to the cultivation history and/or anthropogenic processes of the study sites as the Eiyenkorin Irrigation scheme is just approaching its 12 years of continuous cultivation while Oke-oyi Irrigation had been experiencing crop intensification for more than twenty-five years. Therefore, the delineated MZs will not only promote effective fertilizers and water management for the study sites but also guide management decision for the precision agriculture and sustainable use of the EOIS.

REFERENCES

Boydell, B., McBratney, A.B. 1999. Identifying potential within field management zones from cotton yield estimates. In: Stafford JV, editor. Proceedings of the 2nd European Conference on Precision Agriculture, July 11–15; Odense, Denmark. London: SCI. p. 331–341.

Brejda, J.J., Moorman, T.B., Smith, J.L., Douglas, L.K., Allan, D.L., Thanh, H.D. 2000. Distribution and Variability of Surface Soil Properties at a Regional Scale. Soil Sciences Society of America Journal 64:974 – 982

Bullock, D.S., Ruffo M.L., Bullock D.G., Bollero, G.A. 2009. The value of Variable Rate Technology: An Information-Theoretic Approach. American Journal of Agriculture Economics 91 (1): 209 – 223.

Fagbamiye, A. 2009. Strategies Government can use to boost Agricultural Sector. Nigeria Tribune Wednesday 7th January 2009.

Flint, A.L., Flint, L.E. 2002. In Methods of Soil Analysis, Part 4 - Physical Methods: Dane JH and Topp GC (Eds.). Soil Science Society of America, Madison, Wisconsin, pp. 241-253.

FAO. 2003. Production year handbook. Nigeria's Agriculture and Food Security Challengeshttp://countrystudies.us/nigeria/57.htm

FAO. 1987. “The State of Food and Agriculture”. www.**fao**.org/3/a-ap667e.pdf

Foth, H.D. 2014. Fundamentals of soil science. New York: Wiley. http://oregonstate.edu/instruct/css/330/six/Unit11Notes.htm p. 151.

Fridgen, J.J, Kitchen, N.R., Sudduth, K.A., Drummond, S.T., Wiebold, W.J., Fraisse, C.W. 2004. Management zone analyst (MZA): software for subfield management zone delineation. Agronomy Journal 96:100–108.

Gbadegesin, A.S., Oriola, E.O. 2004. Evaluation of Irrigation farming at Oke-oyi, Kwara State, Nigeria. Agrosearch 6(1): 39 – 47.

Gee, G.W., Or, D. 2002. Particle-Size Analysis. In: Methods of Soil Analysis, Part 4 - Physical Methods: Dane JH and Topp GC (Eds.). Madison, Wisconsin, Soil Science Society of America, pp. 255-289.

Gemtos, T.A., Fountas, S., Agglopoulou, K. 2011. Precision Agriculture Application in Horticultural Crops in Greece and Worldwide. In: Salampasis, M., Matopoulos, A. (eds.): Proceedings of the International Conference on Information and Communication Technologies for Sustainable Agri-production and Environment (HAICTA), Skithos, http://smap.landcareresearch.co.nz/. 451-462.

Google Earth. 2016. Satellite View of the Earth Images @2017 CNES/Airbus.

Henrique, O., Luis, H.B. 2016. Delineation of Irrigation management zones in a Quartzipsamment of the Brazilia semiarid region. Pesq. Agropec. Bras. Brasilla 51 (9):1283 – 1294

Hou-Long, J., Guo-Shun, L., Shu-Duan, L., En-Hua, L., Rui, W., Yong-Feng, Y., Hong-Chao, H. 2012. Delineation of site-specific management zones based on soil properties for a hillside field in central China. Taylor and Franchis- Archives of Agronomy and Soil Science 58(10): 1075–1090

Jiang, X., Wright, A.L., Wang, J., Li, Z. 2011. Long-term tillage effects on the distribution patterns of microbial biomass and activities within soil aggregates. Catena 87: 276 – 280

Lark, R.M. 2001. Some tools for parsimonious analysis and interpretation of within-field variation. Soil Tillage Research Journal 58:99–111.

Marcos, S.R., Matheus, C.S., Amelia, L.P.U., Alex, X. da S.M.M., Italo, H.L.C., Augusto, M.N.L. 2015. Delineation of management zones based on soil physical attributes in an irrigated guava field in the Semi-Arid region, Brazil. African Journal of Agricultural Research Vol. 10(45): 4185 – 4192.

Montenegro, A.A., Montenegro, S. 2006. Spatial variability of classes of texture, salinity and hydraulic conductivity of flat and alluvial soils. R. Bras. Agr. Environmental 10(1): 30 – 37.

Ogunleye, K.Y., Oyediji, T.Y. 2012. Crop Farmers' Knowledge of Climate Change in Ilorin East Local Government Area of Nigeria. Int. Journal http://www.iiste.org, 2:7-13

Ortega, R.A., Santibáñez, O.A. 2007. Determination of management zones in corn (Zea mays L.) based on soil fertility. Computers and Electronics Journal in Agriculture. 58:49-59.

Onwuka, M., Uzochukwu, V.O., Nkwocha, O. S. 2016. Changes in soil pH and exchangeable acidity of selected parent materials as influenced by amendments in Southeast of Nigeria. Journal of Geoscience and Environment Protection 4(5): 80 – 88.

Oshunsanya, S.O., Fagbenro, J.A., Oshunsanya, B.A., Wahab, A.A. 2012. Soil erodibility as influenced by long term fallow in southwestern Nigeria. Conference paper: 2nd West African Organic Conference held between 10th – 13th September 2012 at the Conference Centre, University of Ibadan, Ibadan, Nigeria. WASUMMIT' 2012(2):45 - 59

Peralta, N.R., Costa J.L., Balzarini, M., Castro, F.M., Córdoba, M., Bullock, D. 2015. Delineation of management zones to improve nitrogen management of wheat. Computers and Electronics Journal in Agriculture 110:103 - 113.

Reichert, J.M., Reinert D.J., Braida, J.A. 2003. Soil quality and Sustainable Agricultural System. Ciencia Ambiente 27: 29 – 48.

Reyniers, M., Vrindts, E., De Baerdemaeker, J. 2005. Comparison of an aerial-based system and an on the ground continuous measuring device to predict the yield of winter wheat. European Journal of Agronomy 24 (2006): 87 – 94

Rockstro¨m, J., Hatibu, N., Oweis, T.Y., Wani, S. 2007. Managing water in rainfed agriculture. In Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan: London/International Water Management Institute: Colombo http://www. iwmi.cgiar.org

Rodrigues, M.S., Santana, M.C., Uchoa, A.L.P., Mororo de Menezes, X.S., Cavalcante, I.H.L., Lima, A.M.N. 2015. Delineation of management zones based on soil physical properties in an irrigated guava field in the Semi-arid region, Brazil. African Journal of Agricultural Research 10 (45): 4185 - 4192

SAS Institute. 1999. SAS user's guide: Statistics, SAS Institute, Cary.

Saxton, K.E., Rawls, W.J. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society of America Journal - Soil and Water Management and Conservation. 70 (5): 1569 – 1578.

UNDP. 2015. "Sustainable Development Goals".

Valente, D.S.M., Queiroz, D.M., Pinto, F. de A. de C., Santos, N.T., Santos, F.L. 2012. Definition of management zones in coffee production fields based on apparent soil electrical conductivity. Scientia Agricola 69:173-179.