Assessment of Soil Fertility Status under Continuous Irrigation Farming in Nigerian Savanna

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Abstract

This study assesses soil fertility status under continuous irrigation farming in Nigerian Savanna. Soil samples were collected from eight irrigated farm plots in Zaria while adjacent uncultivated soil was used as the control. Soil samples were collected from 0-20cm (topsoil) and 20-50cm (sub-soil). 108 soil samples were collected and analyzes using standard laboratory methods. Soils were analyzed for texture, bulk density, porosity, moisture content, Soil pH, Organic matter, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K, Na), exchangeable acidity (H+Al), exchangeable cation exchange capacity (ECEC) and base saturation. Descriptive statistic was used to compare the results while Pearson Correlation Coefficient was used to test the elements at 0.01 and 0.05 alpha levels. From the result, the textural grades are loamy. The mean values obtained for each elements at the irrigated plots are: sand (50.38%), silt (39.63%), clay (10%), bulk density (1.38), porosity (47.75%), moisture content (0.26cm^3), pH in water (5.44) and in $CaCl_2$ (5.7). organic matter 1.74%, total N 0.12%, available phosphorus (58.36cmol/kg^{-1}), cations (Ca (7.76cmol/kg^{-1}), Mg (1.48cmol/kg^{-1}), K (0.36cmol/kg^{-1}), and Na (0.61cmol/kg^{-1}), H+Al (0.59cmol/kg^{-1}), ECEC (10.62cmol/kg^{-1}) and base saturation (93%). The control plot showed better improvement in terms of both soil physical and chemical properties. It is recommended that soil testing should be carried out from time to time to monitor the rate of soil deterioration under continuous irrigation.

Keywords: Fertility status, continuous irrigation, soil properties, spatial variation, Zaria

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Introduction

Successful agriculture requires the sustainable use of soil resource because soils can easily lose their quality and quantity within a short period of time for many reasons. Soils through land use change produce considerable alterations (Fu et al., 2000, Yakubu, 2010) while soil quality diminishes after the cultivation of previously untilled soils (Neris et al., 2012). An understanding of how soil respond changes in management practice over time, is essential in effective land management and hence, ensuring soil quality. However, this can only come when a good relationship has been established between soil fertility status and land use practices which may alter soil properties differently (Oyedele et al., 2014; Kiflu and Beyene, 2013). Maintenance soil fertility status is considered an important component of agriculture sustainability by most farmers, environmentalists and government policymakers (Sherwood and Uphoff, 2000; Mallo, 2010). This is because it increases productivity, enables efficient use of nutrients, pesticides, water and lessening of greenhouse gas emissions (Yakubu and Mashi, 2016).

Soil properties affect many processes in the soil that make them suitable for agricultural and other purposes. Assessing soil fertility involves measuring soil properties and using the measured values to detect changes in soil as a result of land use or management practices (Campos et al., 2007). The dynamic nature of the soil describes the condition of a specific soil due to land use and management practices.

Soils are characterized by high degree of variability due to anthropogenic activities that operate at different intensities (Goovaerts, 1998). The selection of key indicators and their critical limits (threshold values), which must be maintained for normal functioning of the soil, are required to monitor changes and determine trends in improvement or deterioration in soil quality for various agro-ecological zones for use at local, national and global levels. Many soil indicators interact with each other, and thus, the value of one is affected by one or more of other parameters (Arshad and Martin, 2002).

According to Wang et al. (2001), climate and geological history are important factors which affect soil properties on regional and continental scales. However, under small catchment scale, land use may be the dominant factor affecting soil properties. Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization and leaching (Celik, 2005; Liu et al., 2010). As a result, can modify the processes of transport and redistribution of nutrients.

Changes in soil properties due to management practice and their consequences on the environment have been studied (Jaiyeoba, 2002; Yakubu and Mashi, 2016; Oyedele et al., 2014) and such changes have direct effects on soil productivity or production capacity. More productivity could be as a result of addition of organic or inorganic fertilizer while less productivity could be associate with soil erosion, loss of organic matter and other degrading processes (Warkentin, 1995; Mallo, 2010).

Land use change, if not carefully monitored, may affects many soil properties negatively which may lead to erosion (Aghasi et al., 2010). soil degradation, which often manifest in soil fertility decline and low agricultural yield. Good knowledge of soil properties in any given environment is necessary for redressing negative trend while ensuring food security and sustainability of the environmental.

Zaria is an urban center in Northern Nigeria. It is a nerve center for commerce, education and transportation in the country as virtually all the major roads and rail routes that link the major cities/towns of the country pass through this area. The area has been a notable hot spot of vegetable gardening in Nigeria. Initially, it was confined to the dry season farming on the upland areas and at backyard of homes. In the last thirty years however, it has extended to the flood plains of the major rivers draining the area. Since the 1990s, expansion has continued markedly along the flood plains of the major Rivers draining the area. Today, Zaria is considered an important vegetable production area due to irrigation and it supplies markets all over Nigeria and even beyond during both the rainy and dry season. The aim of the study is to assess soil fertility status under continuous irrigation farming in Nigerian savannah.

Materials and Methods

Location of Sampling Sites: The study was carried out in Zaria, Northern Nigeria (see Figure 1). Soil samples were collected from Maje, Dankache and Jushi areas where irrigation agriculture takes place all through the wet and dry seasons of the year. The study site is located between latitudes 11° 04’ and 11° 05’N and longitudes 7° 43’ and 7° 44’E (Figure 1). It falls within the Tropical Savanna Climatic zone with distinct wet and dry seasons. The area has a single maximal rainfall regime. Zaria has a mean annual rainfall of 970mm. The temperature is high throughout the year. In dry season, the mean daily maximum temperature is about 37.6°C while the daily minimum could go down to as low as 15°C in January (Yakubu, 2004).

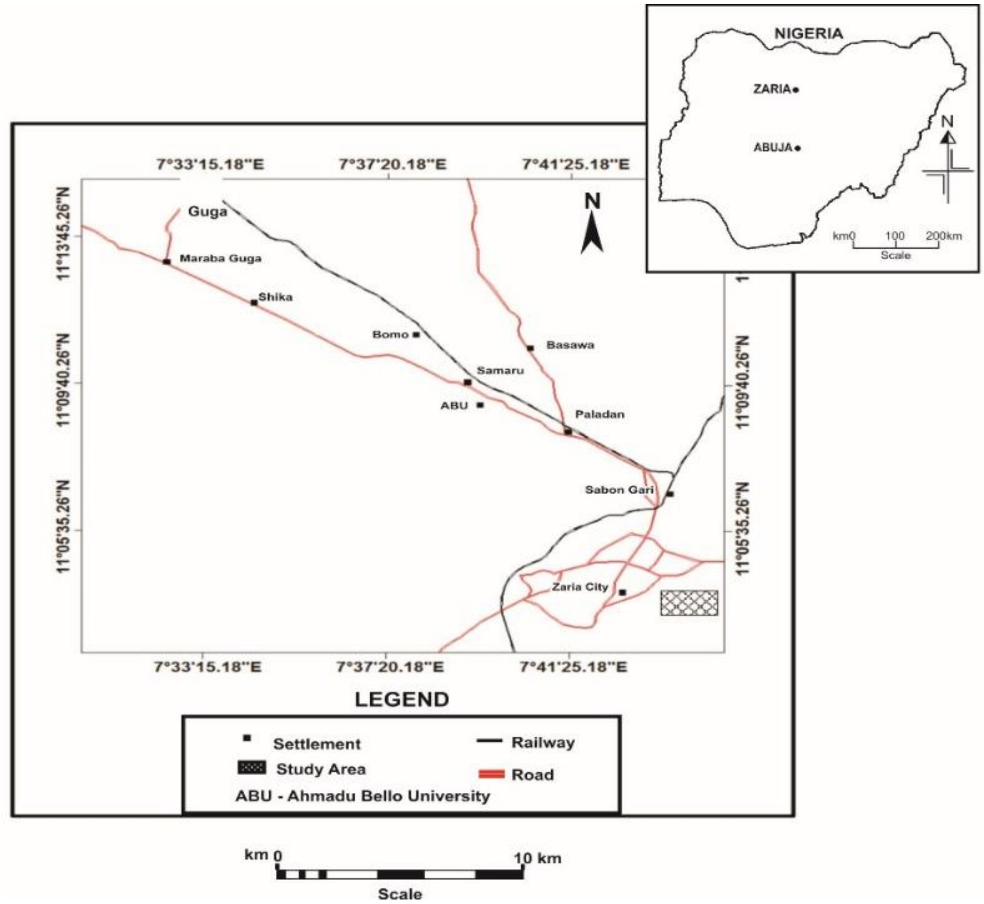

Figure 1: Location of the Study Area

Source: Derived from Zaria Topographic Map, 2017

The geology of the study area is Pre-Cambrian Basement Complex rocks of variable composition (FDALR, 1990). The elevation of the plain ranges from 550 to 740m above sea level (ASL). The topographical nature of the area is a gentle rolling undulating landscape with residual hills of various sizes and shapes. The area is drained largely by three major rivers namely: River Galma, River Kubani and River Saye. The landforms consist mainly of inselbergs, pediment landscape overlying the basement complex made up of nearly level gently undulating plains which are dissected by broad stream valleys (FDALR, 1990).

The soil formed from basement complex rocks and quaternary deposits (Lews, 1962, Bennett, 1980). Under natural woodland, the surface horizons are gray to brown, sandy loam or loamy sand with weak, fine blocky structure. The underlying horizons ranged from light yellowish brown to whitish sandy clay-loam, with few faint or distinct mottles and strong, medium sub-angular blocky structure, while along the wide gentle sloping valleys are the dark vertisols, locally called *fadama* soils. The main source of soil organic matter in this area is biodegradable municipal solid waste (MSW), although at times, supplemented by cattle dung, poultry droppings and chemical fertilizer. The area falls within the Guinea Savanna bioclimatic zone, therefore most of the vegetation has been degraded due to human interference such as agriculture, wood harvesting, overgrazing, and urbanization process among others. The true climax vegetation is almost absent except in the outskirts especially in the Southern suburb where *Isoberlinia doka* is common. The seasonal vegetation covers in the area and occasional intensive rainfall often results to sheet wash in the rainy season and aeolian erosion in the dry season.

Soil Sampling Procedure and Laboratory Analysis

Soil samples were collected from eight different irrigation farm plots in Dankache area of Zaria while adjacent uncultivated soil bordering the road was used as the control. The size of the farm plots ranged from 0.3 to 0.5 hectares. From each of the eight farm plots and the control, six soil samples were collected at depths of 0-20cm and 20-50cm respectively making a total of 108 soil samples collected. Due to the homogeneity of the study area in terms of the factors of soil formation, each farm was treated as a unit of sampling. The undisturbed soil samples collected were taken to the laboratory for immediate treatment while the disturbed six samples collected from each of the two depths were bulked, thoroughly mixed, and a representative sub-sample was taken. The samples collected were air dried, passed through 2mm sieve and stored in plastic bags in readiness for laboratory analysis. Standard Methods as described by Agbenin (1995) were adopted for the analysis of the soil samples. Particle sizes distribution was determined by hydrometer method, Bulk Density (BD) and moisture content (MC) by oven-dried method (as expressed by the weight of the soil before and after over-dried and the volume of the soil), porosity was derived from bulk density and specific particle density of quartzite which is 2.65g/cm^3. The soil pH in water (1:2.5) was determined using glass electrode pH meter solution while the soil pH in $CaCl_2$ (0.01m) was determined using glass electrode pH meter solution. Organic matter (OM) content was determined by Walkey-Black digestion method while the conversion between the value of organic carbon and organic matter was made using Van Bemmelen factor of 1.724 on the assumption that, an average soil organic matter (SOM) contains 58% of organic carbon. Total nitrogen was determined using regular macro Kjeldah method. Available phosphorus was determined using Bray No. 1 method. The exchangeable cations were extracted with 1M NH4, OAC (pH 7.0) to determine K and Na using flame photometer and exchangeable Mg and Ca by atomic absorption spectrophotometer (AAS) while exchangeable acidity (Al + H) was determined using 1N KCl method and base saturation was derived from exchangeable cations and cation exchange capacity (CEC).

Following the laboratory analysis of samples, descriptive and inferential statistics were used to analyze the data. The data were stratified into the different plots and the two selected soils horizons. Pearson correlation coefficient was used to test the levels of significant at 0.01 and 0.05 with the use of Statistical Package for Social Sciences (SPSS).

Results and Discussion

Table 1 shows the mean values of soil properties for the top and sub soils respectively while Table 2 shows the correlation coefficient of the same soil properties at the top and sub soils respectively.

Table 1: Mean for the Control and the Experimental Plots

Property	**Depth (cm)**	**Control**	**Experimented Plots**								**Mean**
			P1	P2	P3	P4	P5	P6	P7	P8	
Sand (%)	0-20	44	52	48	52	54	46	49	54	48	50.38
	20-50	40	46	44	48	50	48	45	48	45	46.75
Silt (%)	0-20	46	40	43	35	35	44	41	38	41	39.63
	20-50	46	40	44	57	36	40	42	42	41	42.75
Clay (%)	0-20	10	8	9	13	11	10	10	8	11	10
	20-50	14	14	12	15	14	12	13	10	14	13
Bulk Density g cm^{-3}	0-20	1.30	1.36	1.50	1.42	1.41	1.29	1.31	1.41	1.31	1.38
	20-50	1.36	1.35	1.51	1.46	1.45	1.50	1.51	1.42	1.55	1.47
Porosity (%)	0-20	51	49	44	46	45	51	50	47	50	47.75
	20-50	49	42	43	45	43	43	45	47	41	43.63
Moisture Content (cm^3)	0-20	1.17	0.23	0.14	0.31	0.30	0.26	0.25	0.28	0.34	0.26
	20-50	0.14	0.21	0.13	0.27	0.28	0.23	0.20	0.28	0.27	0.23
Soil pH H_2O (1:2.5)	0-20	5.3	6.4	5.7	6.2	5.8	6.5	7.0	7.1	6.8	5.44
	20-50	5.0	6.8	5.5	6.0	5.8	6.8	6.7	7.2	6.6	6.43
Soil pH $CaCl_2$ (0.01m)	0-20	5.0	5.5	5.4	5.3	5.0	6.2	6.2	6.6	5.6	5.7
	20-50	4.8	6.2	5.1	5.6	4.9	6.5	6.1	6.6	5.4	5.8
Organic Matter (%)	0-20	1.52	1.41	1.26	1.44	1.31	2.80	2.64	1.56	1.50	1.74
	20-50	1.18	0.66	0.35	1.27	1.11	1.20	1.90	1.92	0.85	1.16
Total Nitrogen (%)	0-20	0.04	0.19	0.16	0.17	0.10	0.07	0.12	0.08	0.04	0.12
	20-50	0.09	0.10	0.05	0.11	0.12	0.18	0.20	0.06	0.07	0.11
Available phosphorous (cmol/kg^{-1})	0-20	6.13	70.54	38.78	36.45	19.34	93.60	98.50	56.06	53.61	58.36
	20-50	6.13	21.50	24.90	20.50	19.34	35.00	45.12	50.74	48.20	33.16
Ca (cmol/kg^{-1})	0-20	2.29 1.43	5.61	3.53	3.00	3.20	16.41	12.44	10.22	6.94	7.67
	20-50		4.92	1.40	1.82	2.10	6.93	6.28	8.15	4.82	4.55
Mg (cmol/kg^{-1})	0-20	0.81	1.69	0.84	1.39	1.06	2.33	2.00	1.38	1.15	1.48
	20-50	0.36	1.31	0.62	0.87	0.50	1.12	0.99	1.72	1.23	1.05
K (cmol/kg^{-1})	0-20	0.35 0.14	0.38	0.28	0.17	0.21	1.10	0.40	0.21	0.13	0.36
	20-50		0.09	0.18	0.17	0.16	0.16	0.12	0.15	0.13	0.15
Na (cmol/kg^{-1})	0-20	0.37 0.30	1.60	0.20	0.19	0.20	1.50	0.24	0.46	0.46	0.61
	20-50		0.40	0.16	0.08	0.20	0.51	0.19	0.19	0.36	0.26
H+AL (cmol/kg^{-1})	0-20	0.20 0.40	0.50	0.50	0.70	0.50	0.70	0.70	0.50	0.60	0.59
	20-50		0.40	0.60	0.60	0.50	0.40	0.50	0.30	0.60	0.49
ECEC (cmol/kg^{-1})	0-20	4.24	9.78	4.85	5.45	5.17	22.04	15.78	12.77	9.21	10.63
	20-50	2.63	6.49	2.96	3.54	3.46	9.12	8.08	10.68	7.24	6.45
Base Saturation (%)	0-20	95	95	90	87	90	97	96	96	93	93
	20-50	85	94	80	83	86	96	93	97	92	90

Table 2: Correlation Coefficients of Soil Properties

Depth	Sand	Silt	Clay	BD	Poro	M/C	p/H	OM	TN	AP	Ca	Mg	K	Na	H+A1	ECEC	B.S
Sand (T) CC	1.00																
(S) CC	1.00																
Silt (T) CC	-0.91**	1.00															
(S) CC	-0.18	1.00															
Clay (T) CC	-0.05	-0.37	1.00														
(S) CC	-0.14	0.33	1.00														
B/D (T) CC	0.52	-0.46	-0.07	1.00													
(S) CC	0.20	-0.05	-0.11	1.00													
POR (T) CC	-0.61	0.60	-0.09	-0.97**	1.00												
(S) CC	-0.40	0.38	-0.20	-0.49	1.00												
M/C (T) CC	-0.55	0.47	0.11	-0.43	0.45	1.00											
(S) CC	0.80**	-0.07	0.02	0.17	-0.26	1.00											
pH (T) CC	0.34	-0.24	-0.19	-0.25	0.26	-0.55	1.00										
CaC0$_4$ (S) CC	0.52	-0.30	-0.44	0.17	-0.32	0.57	1.00										
p/H (T) CC	0.12	0.07	-0.43	-0.20	0.27	-0.42	0.85**										
H2O (S) CC	0.24	-0.11	-0.54	-0.30	-0.07	0.34	0.90**										
OM (T) CC	-0.42	0.39	-0.01	-0.56	0.57	-0.05	0.27	1.00									
(S) CC	0.22	0.07	-0.34	-0.02	0.57	0.39	0.42	1.00									
TN (T) CC	0.46	-0.46	-0.07	0.59	-0.53	-0.54	-0.05	-0.35	1.00								
(S) CC	0.22	-0.14	0.13	0.20	-0.04	-0.07	0.26	0.45	1.00								
AP (T) CC	-0.02	0.14	-0.27	-0.38	0.42	0.57	0.77*	0.59	0.14	1.00							
(S) CC	0.30	-0.27	-0.56	0.58	-0.25	0.45	0.80**	0.45	0.11	1.00							
Ca (T) CC	-0.15	0.24	-0.26	-0.50	0.51	-0.35	0.71*	0.82**	-0.26	0.87**	1.00						
(S) CC	0.32	-0.39	-0.63	0.13	-0.07	0.39	0.92**	0.57	0.33	0.81**	1.00						
Mg (T) CC	0.00	0.04	-0.09	-0.49	0.48	-0.41	0.62	0.75*	0.11	0.90**	0.86**	1.00					
(S) CC	0.37	-0.15	-0.51	0.05	-0.19	0.51	0.93**	0.35	-0.06	0.77*	0.86**	1.00					
K (T) CC	-0.48	0.51	-0.16	-0.48	0.51	-0.03	0.05	0.93**	-0.16	0.55	0.71*	0.72*	1.00				
(S) CC	0.23	0.33	-0.22	0.38	0.14	0.01	-0.41	0.07	-0.19	-0.13	-0.37	-0.37	1.00				
Na (T) CC	-0.42	0.29	-0.44	-0.41	0.48	-0.16	0.20	0.59	0.12	0.53	0.47	0.62	0.68*	1.00			
(S) CC	-0.10	-0.51	-0.05	-0.07	0.34	-0.06	0.31	-0.23	0.25	0.08	0.40	0.42	-0.43	1.00			
H+AT (T) CC	0.35	-0.38	0.35	-0.52	-0.04	-0.76*	0.64	0.39	0.29	0.71	0.57	0.69	0.25	0.13	1.00		
(S) CC	-0.04	-0.35	0.53	0.62	-0.48	-0.05	-0.37	-0.46	-0.09	-0.08	-0.58	-0.42	0.32	-0..38	1.00		

ECEC (T) CC	-0.15	0.34	-0.25	0.25	-0.53	-0.34	0.67*	0.85**	-0.20	0.89**	0.99**	0.91**	0.77*	0.57	0.72*	1.00	
(S) CC	0.33	0.54	-0.64	0.19	-0.09	0.43	0.93**	0.56	0.28	0.85**	0.99**	0.88**	-0.33	0.39	0.94**	1.00	
B/SC (T) CC	-0.33	0.57	-0.64	-0.68*	0.76*	0.17	0.43	0.35	-0.44	0.57	0.71*	0.53	0.56	0.55	0.41	0.72*	1.00
(S) CC	0.28	0.04	-0.44	-0.61	0.11	0.42	0.88**	0.50	0.35	0.67	0.99**	0.81**	-0.56	0.58	-0.00	0.03	1.00

Note: T= Top Soil (0 - 20cm) S= Sub Soil (20-50cm) CC = Correlation Coefficient

*Correlation Coefficient is Significant at 0.01 (2-Tailed) and ** Correlation is Significant at 0.05 (2-Tailed)

The mean value of the various soil fractions over the irrigated plots is higher in the 0 - 20cm depths than in the 20 - 50cm depths while that of silt and clay fractions exhibit opposite trend. The mean values of the sand, silt and clay at the topsoil are 50%, 40% and 10% respectively while at the sub soils the mean values are 46%, 43% and 13% respectively compared with the control with 44%, 46% and 10% (top) and 40%, 46% and 14% (sub) respectively. Correlation coefficient shows significant relationship between sand on the one hand and silt (negative relationship) on the other hand at the topsoil and between sand on the one hand and moisture content (positive relationship) on the other hand at the sub-soil. The soil textural class was loam at both layers. Both silt and clay did not show significant relationship with any element at both layers with the exception of MC and H + Al. The relationship between clay and other elements was negative. The probable reason for the slight decrease of the silt and clay contents at the topsoil over the subsoil may be due to the impact of water infiltration which enables physical eluviation of these particles down the soil profile from the topsoil to lower horizon leading to the clay-enriched sub-soil called argillic horizon (Yakubu, 2010). The soil texture of the different farm plots was found to be similar which shows that the different farm plots did not have significant effect on soil texture of the study area. Hence, texture is an inherent soil property that may not be influenced within a short period of time. Particle size distribution plays an important role in crop production as they impact on soil texture and quality and erosion (Yakubu, 2010; Aderonke and Gbadegesin, 2013).

The mean bulk density value of the surface irrigated soils (1.38) is lower than the sub surface soils (1.47). Although the correlation is only significant with bulk density and porosity at the topsoil, most of the relationships are negatively correlated between each of other soil properties examined. The bulk density mean values range from 1.29 to 1.50 (top soil) and 1.35 to 1.55 (sub soil). When compared with the control, the mean bulk density value of the irrigated plots (1.38gcm^3) is higher than that of 1.30gcm^3 at the top soil for the control while the reverse trend occurred at the sub soil.

The value of bulk density is consistent with the findings of between 1.32 - 1.42 g cm^{-3} (top soils) and 1.33 – 1.45g cm^{-3} (sub soils) obtained by (Yakubu, 2010) in the same ecological zone and between 1.32 - 1.39 g cm^{-3} obtained in Southwestern Nigeria by Oyedele et al., (2009*) under Pterocarpus santalinoides, Gliricidia sepium, Enterolobium cyclocarpum* and *Leucaena* and *leucocephala* intercropped with maize. From the data obtained, both bulk density greatly improved in experimental plots compared to the values obtained at the control. This could be attributed to the fact that the simple implements used as well as the farm management practices adopted in the irrigation farming in the selected plots have not affected the bulk density negatively. Similarly, the 1.75g/cm^{-3} threshold level of soil bulk density, suggested by Jones and Wild, (1975), at which crop roots fail to penetrate the soil has not been reached. At the surface, the moisture content ranges from 0.14 – 0.34cm^3 (mean=0.36cm^{-3}) and it decreased to the range of 0.13 – 0.28 (mean of 0.23cm^{-3}) at the sub soil. In fine textured soils for example, bulk density <0.9 g cm^{-3} may provide insufficient soil-root contact, water retention and plant anchoring whereas bulk density >1.2 g cm^{-3} may impede root elongation and reduce soil aeration 10% (Reynolds et al., 2003).

The values of soil total porosity at both layers of irrigated plots are respectively 47.75% and 43.63%. These values are similar to the value of between 46.79 – 50.19 (top soils) and 45.28 – 49.81 (sub soils) obtained by (Yakubu, 2010) but contrast with the values of 38 - 47% obtained by Oyedele et al. (2009). Air filed porosity is considered inhibiting plant growth while >50% of total porosity is considered quite adequate to provide 10% air filed porosity in silty-clay and clay soils respectively (Hall et al., 1977; Joshua and Rahman, 1993).

The mean value of the moisture content is the highest over control plot (1.17) compared with the values of 0.26cm^3 and 0.23cm^3 obtained at the surface and the sub surface respectively. With the exception of sand (sub soil) and exchangeable acidity (top soil), MC did not show significance between the various plots. The mean value of the moisture content is much greater than the mean value obtained by Jaiyeoba, (2002) in the Nigerian Northern savannah.

Soil pH patterns showed a mean of 6.4 and 5.7 in water and $CaCl_2$ at the surface and 6.4 and 5.8 at the sub surface respectively. According to the classification of Brady and Weil (2002), the soil pH could be described as slightly acidic and decreased toward neutral. Soil pH shows negative correlation in most cases and with few cases of significant relationships with AP, Ca and ECEC at top soils and Mg, ECEC and BS at the sub soils. The slightly acidic soil may be partly due to management practices adopted in each farm plot. At these level, most soil nutrients are readily available to crop roots (Horst, 1998).

The values of soil organic matter at the experimental plots ranged from 1.26 to 2.80% at the topsoil and 0.35 to 1.92 % at the subsoil. The mean values are 1.74 and 1.16% at both top and sub-soils respectively. Organic matter rating on individual plot ranges from low to medium. The mean value of organic matter observed here is relatively higher than the 0.75 – 2.85% observed by Yakubu (2012) under orchard of mango, fallow land, grazing land, irrigated plot and rain-fed plot. But much lower than the values of 4.55%, 3.2% and 3.3% obtained under forest, fallow and cocoa plantation respectively in South-Western Nigeria by Ekanade (1989).

Based on the ratings for soil fertility classes in the Nigerian savanna (Holland et al. 1989), soil total nitrogen is rated very low with a weight of 0.12% at the top and 0.11% at the sub soil. Whenever the natural condition of the surface soil is disturbed, it leads to increase runoff and loss of large amounts of nitrogen from soil surface layer (Aghasi et al., 2010). The mean values of available phosphorus significantly increased from 19.34 – 98.50cmol/kg (top soil) and 19.34 – 50.74cmol/kg (sub soil) in experimental plots to 6.13cmol/kg at both layers respectively for the control. These values range from high to very high at the irrigated plots (Holland et al. 1989). The high amounts observed in all the plots could be as a result of application of fertilizer so as to boost the potassium content.

The mean values of exchangeable cations (Ca, Mg, K, Na) are much higher at experimental plots (7.67, 1.48, 0.36, 0.61 cmol/kg^{-1}) than the values of 2.29, 0.81, 0.35, 0.37 cmol/kg^{-1} obtained at the control respectively and they are higher on the upper layer than at the lower horizon. Exchangeable cations did not show significant relationship with soil physical properties rather, the correlation is mostly negative. The correlations between chemical properties on the other hands are positive and are mostly significant in most cases. Greater immobilization by plants and animals in the top horizon, eluviation of materials from the top horizon and deposited at the lower horizon or greater weathering and release of the elements in the lower horizon (Fitzpatrick, 1980) could be the possible reasons. Generally, the very low fraction of clay and organic matter content of the soils are responsible for low cations retaining ability of the soil and hence it's low capacity to hold nutrients against leaching.

Similarly, the mean values of exchangeable acidity of 0.59 and 0.49 cmol/kg at both top and sub soils are greater than the values obtained at the control 0.20 and 0.40cmol/kg respectively. Generally, the exchangeable acidity is very low and suggesting that the soils have no acidity problem. With the exception of MC at the topsoil, Al + H did not show significant relationship at both soil layers.

Soil ECEC is highest on the experimental plots 4.85 to 22.04 (mean=10.63 cmol/kg) at the surface layer than the control (4.24). These values of the experimented plots are rated low. At the top soil, ECEC is significant with OM and K while it is significant with pH, available phosphorus, Ca, Mg and H + Al at both layers. While addition of organic matter increases the amount of exchangeable bases in the soil (Urioste et al., 2006), intensive cultivation and constant use of mineral fertilizer often enhance loss of base cations through crop harvesting and leaching or translocation (Yakubu and Mashi, 2016).

The soils have very high base saturation at both top and sub soils with mean values of 93% and 90.13% respectively. For the eight experimented plots and the control, the base saturation followed trend of: P5 > P6 = P7 > P1 = Control > P8 > P4 = P2 > P3. Correlation coefficient is only significant between base saturation (BS) and BD, porosity, Ca, and ECEC at the top soil while at the sub soil, it is significant with each of the following: pH, Ca and Mg. The results obtained in this study contradicts the findings of Yakubu (2012) where the value at the top layer (48.55%) was lower relative to the subsoil (68.64%). This result conforms to the values obtained by Lombin and Chude (1988) in north-western Nigeria.

Conclusion

This study showed variations in soil fertility status under continuous irrigation farming in Zaria. Although soil properties of the irrigated farm plots indicated that the soils are deficient in most of the nutrients, but the irrigated farm plot are better than the control for optimal production in terms of nutrient status due to constant addition of external input such as organic and in organic fertilizers commonly used in the area. Giving the right management techniques will improve agricultural productivity and optimal production in the area. Sustainable agricultural production in the area can only be achieved by using of appropriate measures of inputs to irrigated farm plots and appropriate management techniques to augment the natural endowment of the soil. It is recommended that soil testing should be carried out from time to time to monitor the rate of soil deterioration under continuous irrigation in the area.

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