AN EVALUATION OF PHYSICO-CHEMICAL PROPERTIES OF SOILS FROM IRRIGATED AREA OF WAYA DAM IN BAUCHI STATE, NIGERIA

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Abstract

A study was carried out to evaluate the physico-chemical properties of soils in Waya Dam irrigated area of Bauchi State, Nigeria. A total of eighty composite soil samples comprising five from each of the irrigated plots of 15.24m by 15.24m dimensions at 0-5, 5-10, 10-15 and 15-20cm depths were collected. The soil samples were analyzed for their physico-chemical properties using standard procedures. Results obtained showed that the soils were mainly sandy loam in texture. The mean values of soil pH (1:1), percentage organic carbon, total nitrogen and available phosphorus at soil depths of 0-20cm were 5.38, 0.54, 0.27 and 4.17 for cultivated land. The mean values of exchangeable bases (Ca, Mg, K , Na CEC) in Cmo(+) Kg-1 and SAR of the soils for the same rang of soil depths were 2.29, 0.60, 0.17, 0.13, 4.28 and 0.28 respectively. The mean values of soil pH (1:1), percentage

organic carbon, total nitrogen and available phosphorus at soil depths of 0-20cm were 5.67, 0.97, 0.08 and 8.04 for uncultivated land. The mean values of exchangeable bases (Ca, Mg, K , Na CEC) in Cmol(+) Kg-1 and SAR of the soils for the same rang of soil depths were 2.29, 0.61, 0.20, 0.13, 4.35 and 0.28 milliequivolent/litre respectively. It was found that the soil was strongly acidic while chemical parameters were generally low when compared with the critical limits for interpreting level of analytical parameters. The results also indicated that soil depth and location significantly (p=0.05) influence the silt and CEC distribution in the study area which is for now free from salinity and sodicity problems. The application of organic matter, complimented by application of inorganic fertilizer is recommended for sustainable crop production in the study area.

Key words: Physio-chemical properties, irrigated area, Waya Dam, Bauchi

Soil quality is how well soil does, what we want it to do. More specifically soil quality is the capacity of specific kind of soil to function within natural or ecosystem boundaries or sustains plant and animals productivity, maintain or enhance water and air quality and support human health and habitation (Karlen, Mausbach and Doran, 1997).

Under both small and large scale irrigation system the excessive application of water adversely affect the soil quality. It usually results in water logging in poorly drained areas as well as in salt build up. The development of salinity is a challenge to performance of irrigation in Agriculture. Unfavorable soil water air relationship and decrease in crop production are the consequences. The rate and amount of salt accumulation in soil depends on the frequency and method of water application. (Michael, 1978).

Soil according to Kingyang (2007) and Richard (1954) is defined as collection of natural bodies on the earth surface supporting plant with lower limit at the depth of either unconsolidated minerals or organic materials lying within the rooting zone of plant. Karlen, Andrews and Wienhold (2008) defined soil as natural materials formed from a mixture of minerals and decaying organic matter, which covers the earth in a thin layer. Soil is a natural body of loose unconsolidated dilated materials which constitute a thin layer several meters deep on the earth surface. It is derived from weathered parent materials and decaying organic matter and is composed of soil particles with liquid or grasses occupying the space between the particles (Agboola, Ndaeyo and Kalu (. 1998).

Salts accumulates naturally in some surface soil of arid and semi arid region because there is insufficient rainfall to flush them from upper soil layers. The salts are primarily chloride and sulfates of calcium, magnesium, sodium and potassium. They may be formed during the weathering of rocks and minerals brought to the soil through rainfall and irrigation. Other localize but important source are fossils deposit of salt laid down during geological time in the bottom of now extinct lakes or oceans or underground saline water pools. These fossils salt can be dissolved in underground water that move horizontally through varying underlying impervious geological layers and ultimately raise to the surface of soil in the low-lying parts of the landscape, often forming saline seep. The water evaporates leaving salt in place at near the soil surface. Unfortunately, high level of these salts cannot be tolerated by most plants, a fact that severely limits the use of some salt affected soil (Andrews and Karlen,2004).

The Sodium Absorption Ration (SAR) of a soil extract take into consideration that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions.

The Sodium Absorption Ration (SAR) also is used to characterize the irrigation water added to the Soil and is calculated using the following equation

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++}/2}} \quad (1)$$

Where:
Na= sodium ions
Ca= Calcium ions
Mg= Magnesium ions (Ibrahim and Garba, 1995).

Exchangeable sodium percentage (ESP), sodium absorption ration (SAR) characteristic and soil pH salt affected soils can be used to classify soils as: Saline soil, saline sodic soil and Sodic respectively. The natural processes that result in the accumulation of natural soluble salt are referred to as Salinization. Saline soils contain a concentration of natural salt sufficient to interfere with the growth of most plant. Salt are commonly brought to the soil surface by evaporating water, creating a white crust which account for the name white alkali that is some time used to designate these soils. (Jones and Wild, 1975).

In the last few years, Bauchi state has embarked on expansion of irrigation Agricultural farming system through the large scale irrigated project. The land under project has suffered a number of setbacks. These include decrease in crop yield attributing this to the deterioration in soil qualities. Yet no any systematic effort appears to have been made to ascertain this condition. This research work seeks to analyze the soil quality by determining the physio-chemical properties of Waya dam irrigated project area of Bauchi State with a view to preferring solution.

Materials and Methods

Location of the Study Area: Waya dam irrigation project site located between longitudes 10^0 $15^/$ and 10^0 $30^/$ E and latitude 9^0 $45^/$ and 10^0 $20^/$ N, north eastern zone of Nigeria. The dam is about Twenty five kilometer away from Bauchi main town along Maiduguri road. The sampling site is located along Maiduguri road

Reagents Used: These include Potassium dichromate, sulphuric acid, sodium hydro oxide, potassium sulphate, copper sulphate, bromocresue green, methyl red, ammonium acetate, sodium acetate, hydrochloric acid, nitric acid, nitric acid, and perchloric acid.

Soil Sampling: The cultivated land was divided into four plots as A, B, C and D measuring 50ft by 50ft (15.24m by 15.24m). In each plot, four sample were collected from a depth of 0-5cm, 5-10cm, 10-15cm, using auger. The total samples collected from cultivated land were 64.

The uncultivated land was also divided into four plots 50ft by 50ft (15.24m by 15.24m) marked as E,F, G and H. four samples of soil were collected from each plots from the depth of 0-5cm, 5-10cm, 10-15, and 15-20cm. A total of 16 soil samples were collected from the virgin land which make a total of 76 soil sample from both cultivated and virgin (uncultivated land).

Physical Analysis: The soil samples were collected air-dried, ground and passed through a 2mm sieve. The 2mm sieved soil samples were subjected to standard laboratory analysis described by Blake (1982) where 5g soils was shaken with 50ml of 0.1 NHCL solutions for period of 30 minutes and filtered. The concentrations of micronutrients from the filtrate were determined on atomic absorption spectrophotometer A.A.S model VGP 210. The soil physical properties were analyzed and categorized into percentages of sand, silt and clay so as to determine the soil texture.

Chemical Analysis: The pH value of the soil samples were read in both water and calcium chloride ($CACL_2$) in the ratio of 1:1 and 1:2 using pH meter. The total nitrogen in the soil sample was determined using regular macro NJKeldal method as described by Bremner (1965). Standard sulphuric acid was used to titrate the distilled ammonia (NH_3) tapped by is boric acid in the present indicator. (methyl red). This was determined by leaching the soil ammonium saturation method and values of individual bases were read using atomic absorption spectrometer (A.A.S) as described by (Bremner, 1965). The cation exchange capacity (CEC) was determined using ammonium saturation method as described by (Bremner, 1965). The excess acetate was removed by repeated washing with alcohol. The absorbed Ammonium ions were distilled by NKjeldal method.

Results and Discussions

Results of Physical Analysis: The results of the physical sieve analysis of soils samples from plot A, B, C, & D of cultivated areas of Waya Dam area as presented in tables 1, while that of uncultivated land from plots E, F, G, and H is presented in table 2. The sand fraction in cultivated Land was found to ranges from 73.05%-70.43% with a mean of 72.59%. It contained significantly (p=0.001) higher sand content. In the uncultivated land, the sand fraction ranged from 71.64% - 65.59% with mean of 69.15%. The result showed that there is significantly (P=0.001) high sand content in both cultivated and uncultivated lands. There was no significant (P=0.05) differences in the distribution of sand with depth. But sand fraction is irregularly distributed down the soil profile.

The sand fraction of the project area was also high with the content decrease with depth. The dominance of the soil separate by sand fraction may be due to the nature of the parent material, which is predominantly sand stone.

The silt fraction of cultivable land ranged from 15.43% - 15.43% with a mean of 43.12%. On uncultivated land the silt fraction ranged from 16.19% - 14.17% with a mean of 14.92%. The result showed that there is significant difference of silt content (P=0.001) of the cultivated and uncultivated land.

The silt content decrease with depth with an apparent increased in the section. This may be an indication that weathering of the minerals is still going on converting minerals from parent materials to silt which could also be weathered to clay with time (Voncir, 2002).

The distribution of clay fraction varies significantly (P=0.01) between the uncultivated land and cultivated soil of the irrigation project in table 1. The uncultivated land has higher significantly clay content than the cultivated land in which the lowest clay value was recorded at section c (13.59%) and the highest clay (17.84%) value was found at the uncultivated land (Virgin land).

The clay fraction increased with depth, this could be due to eluciations/illuviation pedogenic processes being prominent according to Ojanuga (1979). Brady (1999) reported that that the general depletion of clay in the surface section could be due to the eluviations/illuviation processes being prominent.

Table 1. Particle Size Distributions of Soil Samples from Cultivated Land

Depth(cm)	Plots	Sand%	Silt%	Clay%	Texture
0-5	A	73.05	13.89	14.27	Sandy
5-10	B	75.49	10.36	14.15	L
10-15	C	70.43	15.43	13.59	o
15-20	D	71.37	13.74	14.52	a
Mean		72.59	43.12	14.14	m
SED		-	-	-	
LSD		***	***	***	-
					-
					-
					-

SED=Standard error of deviation
LSD=Least standard deviation

Table 2. Particle Size Distributions of Soil Samples from Uncultivated Land

Depth(cm)	Plots	Sand%	Silt%	Clay%	Texture
0-5	E	68.59	15.86	15.26	Sandy
5-10	F	65.59	16.19	14.66	L
10-15	G	71.64	14.17	14.26	o
15-20	H	70.79	13.45	15.31	a
Mean		69.15	14.92	14.87	m
SED		7.60	4.62	1.22	
LSD		NS	NS	NS	- - - -

Results of Chemical Analysis of Soil Samples from Waya Dam

The mean values of pH of the cultivated and uncultivated lands were found to be 5.38 and 5.67 from tables 3 and 4 respectively. The acidic nature of the soil may be due to leaching at basic cation leaving the top soil acidic since the soil were under irrigation or due to crop uptake. The reaction of soil solution represent the degree of acidity or alkalinity caused by the relative concentration of hydrogen ions (H^+) or hydroxyl ions (OH^-) present in the solution.

Different soils have different level of pH because of the different degree of pedological process they are exposed to (Karen and Bingham, 1985).At these different levels, it could be found to have either a negative or positive effect on the availability of some plant nutrients present in the soil.

The mean percentages of organic carbon were found to be 0.54 and 0.79 for both cultivated and uncultivated lands. They were rated very low when compared with critical limits for interpreting levels of analytical parameters in appendix. The low organic carbon content could be due to the rapid organic matter mineralization thereby preventing any appreciable level of humification. It may also be reflection of the sparse natural vegetation as a consequence of cultural practice which encourages crop residue removal as confirmed by (Jone and Wild, 1975).

The mean percentages of total Nitrogen for both cultivated and uncultivated lands were found to be 0.27 and 0.08 respectively which could be rated as very low when compared with the critical limits for interpreting levels of analytical parameters. This confirms Kowal and Kassam (1973) assertions that soil content of nitrogen depends on the organic matter contents which is generally low especially in the savanna region of Nigeria.

The mean amount of available phosphorous in both the cultivated and uncultivated lands in tables 3 and 4 were found to be 4.17 $mgkg^{-1}$ and 8.04 $mgkg^{-1}$ respectively. This can be rated low when compared with the critical limits for interpreting levels of analytical parameters. This finding agree with the findings of (Ipimidun, 1972) who reported extreme low values of available s phosphorus in Nigerian savanna soil.

Table 3. Result of PH, Organic Carbon, Total Nitrogen and available Phosphorous of soil samples of Cultivated Land from Waya Dam.

Depth(cm)	Plots	PH (1:1)	OC(%)	T/N(%)	AVP (mgkg-1)
0-5	A	5.23	0.72	0.07	6.09

5-10	B	5.23	0.72	0.07	6.38
10-15	C	5.71	0.39	0.04	4.15
15-20	D	5.34	0.36	0.36	0.04
Mean		5.38	0.54	0.27	4.17
SED		-	-	-	-
LSD		***	***	***	***

Table 4**: Result of PH, Organic Carbon, Total Nitrogen and available Phosphorous of Soil Samples of Uncultivated Land from Waya Dam.**

Depth(cm)	Plots	PH	OC(%)	T/N(%)	AVP (mgkg-1)
0-5	E	5.53	0.68	0.07	7.66
5-10	F	5.77	0.86	0.08	8.17
10-15	G	5.88	0.92	0.09	8.75
15-20	H	5.51	0.73	0.07	7.59
Mean		5.67	0.79	0.08	8.04
SED		-	-	-	-
LSD		***	***	***	***

From the results obtained in tables 5 and 6, it was found that the mean quantities of calcium content were medium. The mean value of 2.29 Cmol(+)kg^{-1} was recorded for both cultivated and uncultivated lands. The medium content may be due to the type and chemical composition of the parent materials, which formed the soils. The parent materials must have been rich in calcium. The environmental condition (semi arid) probably also aided the accumulation of calcium. According to Fitzpatrick (1986), carbonates particularly calcium carbonate are the first substance to start accumulating as the climate becomes arid.

The mean amount of magnesium content were found to be 0.60 Cmol(+)kg^{-1} and 0.61 Cmol(+)kg^{-1} in both cultivated and uncultivated lands. They were moderate with irregular distribution within the sections with higher content occurring in the virgin land. The magnesium level in the soils according to Mengel and Kirkiby, 1987, depend on factors including soil type and the type of parent materials. Soil formed from parent materials rich in magnesium as basalt are well supplied with magnesium while soil formed from parent materials low in magnesium have low magnesium contents. The higher concentrations obtained in the lower section may be due to leaching losses from the surface section. Magnesium, like calcium is relatively easily leached from the soil and the rate of leaching is normally higher in sandy soils as reported by Voncir, 2002. The nutrients varied within lower limits between cultivated land and uncultivated land.

The mean amount of potassium content were found to be 0.77 Cmol(+)kg^{-1} and 0.20 Cmol(+)kg^{-1} respectively for both lands which was rated medium. The low potassium content may be due to loss of plant residues through bush burning and the subsequent washing away of the ashes by running water, grazing by animals; and leaching. Low potassium may also be attributed to the clay content of the soil.

The mean amount of sodium content were found to be 0.13 Cmol(+)kg^{-1} in both the cultivated and uncultivated lands. It was rated medium when compared with the critical limits for interpreting levels of analytical parameters. The annual precipitation is

insufficient to leach the salts which are left to the surface as the moisture evaporates.

The mean amount of CEC for both soils from cultivated and uncultivated lands 4.35 Cmol(+)kg^{-1} and 4.35 Cmol(+)kg^{-1} respectively. The low value could be due to the fact that the organic matter content of the soil was low and the increase with depth could be associated with increased level of clay in the lower section. According to Fitzpatrick, l986 the low CEC in the surface section could be due to low organic matter while the increase content with depth could be due to increase in clay content. Generally the SAR was low on both the cultivated land and uncultivated land. There mean values were found to be 0.28miliequivolent/litre.

Table 5: Results of the Exchangeable Bases and SAR of Soil Samples from Cultivated Land

Depth(cm)	Plots	Ca [Cmol (+) kg-1)	mg [Cmol(+)kg-1]	K [Cmol(+)kg-1]	Na [Cmol(+) kg-1]	CEC [Cmol(+) kg-1]	SAR Milli eq/lt
0-5	A	2.18	0.64	0.18	0.17	4.23	0.13
5-10	B	2.18	0.58	0.20	0.12	4.10	0.12
10-15	C	1.76	0.49	0.15	0.11	3.46	0.9
15-20	D	1.65	0.48	0.15	0.15	3.16	0.10
Mean		2.29	0.60	0.17	0.13	4.28	0.28
SED		-	-	-	-	-	-
LSD		***	***	***	*	NS	NS

Table 6: Result of Exchangeable Base and SAR of Soil Samples from Uncultivated Land

Depth(cm)	Plots	Ca [Cmol (+) kg-1)	mg [Cmol(+)kg-1]	K [Cmol(+)kg-1]	Na [Cmol(+) kg-1]	CEC [Cmol(+) kg-1]	SAR Milli eq/lt
0-5	E	2.20	0.62	0.18	0.16	4.07	0.12
5-10	F	2.37	0.62	0.19	0.11	4.53	0.10
10-15	G	2.38	0.60	0.21	0.12	4.46	0.80
15-20	H	2.20	0.57	0.21	0.11	4.35	0.10
Mean		2.29	0.61	0.20	0.13	4.35	0.28
SED		-	-	-	0.06	-	1.10
LSD		***	***	***	NS	***	NS

Conclusion

This study was carried out at Waya Dam Irrigation Project Area in order to investigate the soil quality. The soil samples were collected and analyzed for physical and chemical properties. The result obtained show that the soils were mostly sandy loam in texture and slightly acidic. The results of both the physical and chemical analysis of the soil samples from the cultivated and uncultivated areas of Waya Dam were found to be low in organic carbon, total nitrogen and available phosphorous content with sandy to clay sand texture and slightly acid in nature. All these are some of the soil constraints for crop production. An integrated management package that will minimize and improve both the physical and chemical condition of the soils for the enhancement and sustenance of their production is needed. It is therefore recommended that farmers should adopt method of applying organic manure and inorganic fertilizer application in order to boast the overall fertility of the soil for optimum production for the study area.

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Appendix D. Critical limits for interpreting levels of analytical parameters

Parameter	Rating			
	Low	Medium	High	Unit
Calcium	<2	2 – 5	>5	$Cmol(+)kg^{-1}$
Magnesium	<0.3	0.30 – 10	>1.0	$Cmol(+)kg^{-1}$
Potassium	<0.15	0.15 – 0.30	>0.30	$Cmol(+)kg^{-1}$
Sodium	<0.1	0.10 – 0.30	>0.30	$Cmol(+)kg^{-1}$
C.E.C (soil)	<6	6 – 12	>12	$Cmol(+)kg^{-1}$
C.E.C (clay)	<15	15 – 25	>25	$Cmol(+)kg^{-1}$
Exchangeable acidity	< 2	2 – 5	>5	$Cmol(+)kg^{-1}$
Base saturation	<50	50 – 80	>80	%
Organic carbon	<10	10 – 15	>15	gkg^{-1}
Total nitrogen	<1.0	1 – 2	>2	gkg^{-1}
Available phosphorus	<10	10 – 20	>20	$mgkg^{-1}$
Iron	\ <4.5	4.5 – 10.00	>10	$mgkg^{-1}$
Manganese	<1.0	1.0 – 5.0	>5.0	$mgkg^{-1}$
Zinc	<0.8	0.8 – 2.0	>2.0	$mgkg^{-1}$
Copper	<0.2	0.2 – 1.0	>1.0	$mgkg^{-1}$
Boron	<0.5	0.5 – 2.5	>2.5	$mgkg^{-1}$
SOIL DEPTH				
Very shallow			<25cm	
Shallow			25 – 50cm	
Moderately deep			50 – 100cm	
Deep			100 – 150cm	
Very deep			>150cm	
SOIL REACTION				
Ultra acid			pH<3.5	
Extremely acid			3.5 – 4.4	
Very strongly acid			4.5 – 50	
Strongly acid			5.1 – 5.4	
Moderately acid			5.5 – 6.0	
Slightly acid			6.1 – 6.5	

Source: Esu (1990)