AN ASSESSMENT OF SOIL PROPERTIES OF WATARI IRRIGATION PROJECT, KANO STATE NIGERIA

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ABSTRACT

This research was carried out in Watari River Irrigation Project, located on the slopes of Watari River valley in Bagwai local government of Kano state with aim of assessing soil properties. A total of 32 representative samples were randomly collected from the eight sectors (0-20cm) depth. The samples were treated and analyzed for physical, chemical and fertility related indices. The results have shown that all the eight sectors had sand dominated texture. The mean pH in the soil ranged from 5.50 to 5.95. The EC ranged between 0.49 to 1.30cmol/kg, the Cl^- ranged between 0.29 to 1.07cmol/kg and SAR ranged between 0.13to 0.72. The mean soil organic carbon across the sectors ranged between 0.62 to 1.49%. The total nitrogen ranged between 0.0043 to 0.084% while NH_4^+ and NO_3^- Forms of nitrogen ranged between 0.0043 to 0.0065cmol/kg and 0.0025 to 0.0065mg/kg respectively. The CEC ranged between 9.04 to 12.68cmol/kg. The exchangeable bases ranged from 3.13 to 4.25; 1.06to1.73 and 1.28 to 2.08cmol/kg for Ca, Mg and K respectively. The boron content in the soil across the sectors ranged between 4.09 to 6.34mg/kg. The research recommended that irrigation, fertilizer and agrochemical management as well as careful monitoring of soil and water condition should be adopted as strategy to maintain and improve the salinity status of the sectors. Extension should also be focused on water use efficiency, soil conservation practices such as incorporation of organic residues and conservation tillage practices.

Keywords: Assessment, Fertility, Soil properties, Watari River and Irrigation

INTRODUCTION

Adequate management of soil is required to achieve the Millennium Development Goals of the United Nations of food security by the year 2015. One of such efforts by government to develop land for food production is in the area irrigation scheme. Soil is one of the important natural resources on the earth surface. In agricultural production, it is an integral part of the ecological system which produces food and fiber. For agricultural crops, soil serves as a medium which is capable of physically supporting plants as well as acting as store house for the water and nutrients essential for plants growth.

However continuous use of soil for irrigation may pose some adverse effects on both soil and water quality. According to Ngailo et al, (1999), many traditional irrigated agricultural systems in the tropics are characterized by negative mineral element balances essential for plant growth and development. Many factors are responsible for the quality of any given soil and these factors are generally called indicators and they include agro-climatic, hydrogeology and cropping/cultural practices (NAS, 1993). Although, it is difficult to measure (Cannon and Winder, 2004), however it still needs to be evaluated regularly, because nearly all land uses depend on healthy soil functions (USDA, 2002). The necessity for regular investigation of soil in order to evaluate its quality is essential because of the simple fact that land use and management can change the capacity of the soil to function (Karlen, 1997; USDA, 2002). There are three basic processes through which soil quality can be degraded namely, physical

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(erosion); chemical (salinization, alkalinity, nutrient deficiency and heavy metal contamination) and biological (This borders on loss of organic matter) (NAS,1993).

Due to complex interactions between several factors such as soil and crop management, farming systems and soil fertility, production of both food and cash crops have declined, thus threatening food security in these areas (Ngailo, et al, 1999). In many areas, researches have shown that continuous cultivation of land, subjected to irrigation without proper management practices, result into soil fertility decline (Smalling and Braun,1996; Smalling et al, 1997; Scoones,2001,Ndakidemi and Semoka, 2006).

Though there are no generally agreed benchmarks of establishing the extent of declines in fertility levels of soils under irrigation farming practices, some key soil fertility indicators have previously been reported by several other researches (Tisdale and Oades,1982; Brady and Weil,2002). They include soil pH, soil organic matter, total nitrogen, available phosphorous, Cation exchange capacity, exchangeable bases, salinity, and sodicity status and the amount of extractable N, P, K, Mg and Ca.

This research assessed soil condition and fertility in the Watari Irrigation Scheme with a view to making proper recommendations on the implications of the current trend of land use in the area.

STUDY AREA

Watari Irrigation Scheme is a medium scale irrigation project located on the slopes of the Watari River valley in Bagwai Local Government, which is about 18km from Bichi. It is located at the Northwestern part of Kano between latitudes $12^0$6’ 54.54’’N and 12 ^{0}9’ 17.8’’N and longitudes 08^o 11’ 50.62’’E and 08^o 16’ 28.05’’E The main canal is about 10km long, while the command area consists of 5 sectors numbered 1 through 4 and sector 8 the kanyu pilot farm. The net irrigable land area in rounded figure per sector is as follows:

Table 1. The Area of Irrigable Land in Watari River Irrigation Scheme

Sector	*Hectare*
1	160
2	170
3	216
4	72
8	72
Total	690

Source: KNARDA, 2011

Studies have shown the importance of examining physical parameters in monitoring the productivity and suitability of soil to different management activities. Furthermore, most soil scientists also hold the view that fertility and salinity in irrigation sites are good indicators of land management practices (Dawaki, 1996). A combination of the parameters tested is very necessary in assessing the soil quality as well as vulnerability to change is necessary especially in Watari area.

METHODOLOGY

A total of 4 soil samples were randomly collected from each of the 8 sectors from a depth of 0-20cm thereby making a total of 32 representative samples which were treated and analyzed for physical chemical and fertility related indices.

The samples collected were placed into polythene sample bags taken to the laboratory air dried and sieved with a 2mm mesh sieve for analysis. The treated soil samples were subjected to analyses using the following methods;

Particle size distribution was determined using bouyouscos (1957) method. USDA Textural triangle was also used for determining textural classes.

Organic carbon was determined using the Walkley-Black (1934) method. Phosphorus (P) content determination was done using the colorimeter (CECIL CE 373) method using the sodium hydrogen carbonate extraction. The determination was according to the Bray and Kurtz (1945) method.

The determination of exchangeable bases was done with flame photometer (JENWAY PFP7) after extraction using ammonium acetate extraction technique. The CEC was determined using the ammonium acetate saturation method as outlined by Hesse (1971).

The total nitrogen was determined using the kjeldal Digestion method. P^H was determined using the 1:2.5 soil water ratios.

RESULTS

Soil Assessment

The results of the soils analysis of the various sectors of the Watari Irrigation Scheme are presented in the following Tables 1, 2 and 3. The results are grouped into three sections namely physical properties, salinity and fertility statuses.

Soil Physical Properties of the Watari Irrigation Scheme

The physical condition of the soil was assessed for particle size distributions in the soil and subsequently translated into textural classes. These results are presented in Table 1. Across the eight sectors 3, means and values ranged between 63 – 85%, silt values ranged between 6.5 to 20% and clay values ranged between 10 – 18.5%. The highest sand content was recorded at sector 3, which correspondingly also had the least content of both sand and clay.

Interpretation

Going by these results, it is evidently clear that the soils in all the eight sectors have sand dominated texture. Furthermore, while Sectors 1, 4, 5, 6 and 7 have sandy loam texture; sectors 2 and 7 have sandy clay loam textures; while sector 3 having loamy sand texture.

The predominance of sand particles in arid and semi-arid climates is not uncommon because many of them were formed from aeolian deposits blown from across several thousands of kilometers (Mortimore, 1989). Such deposits are commonly found covering the surfaces of underlying soils that may be formed from other parent materials such as the alluvial deposits common in *fadama* areas such as the one investigated. It may be the influence of the alluvium that must have raised the clay and silt values in sectors 2 and 7.

Management Implications

Sandy textured soils are prone to erosion because of the low silt and clay contents which play very important role in binding particles and creating stable structures that can resist erosive factors such as wind and water (Adamu, 1997). Such soils are also prone to excessive

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leaching of nutrients because of low water holding capacity and limited binding sites for cations. Because of this low water holding capacity, the frequency of irrigation will also have to increase and this will affect water use economy and salinity status of the soil. The best management options for such soils would be conservation tillage which minimizes the impact of machines and tools, enhances structural grade thereby improving water retention as well as improving the overall organic matter content of the soil which will improve the nutrient retention ability of the soil (Omar,2011). The practice may also benefit even those sectors with appreciable clay because it will reduce their proneness to compaction which is a possibility with increased machinery use.

Table 2. Physical Properties of the Watari Irrigation Scheme

Sector	*CLAY*	*SILT*	*SAND*	*TEX.CLASS*
1	13.5	18	68.5	Sandy loam
2	17	20	63	Sandy clay loam
3	8.5	6.5	85	Loamy sand
4	14.5	10	75.5	Sandy loam
5	12	13	75	Sandy loam
6	10	15	75	Sandy loam
7	18.5	17	64.5	Sandy clay loam
8	13	10.5	76.5	Sandy loam

Source: Lab. analytical data, 2011

Salinity Status of Soils of the Watari Irrigation Scheme

The mean values of the major indicators of soil salinity for the sectors are shown in Table 2. The mean pH in water ranged between 6.13 and 6.48 while in salt it ranged from 5.50 to 5.95. The EC ranged between 0.06 to 0.23dS/m. No CO_3^{2-} was detected across the eight sectors. While the HCO_3^- mean ranged between 0.49 to 1.30cmol/kg, the Cl^- mean ranged between 0.53 to 1.13cmol/kg. Na mean ranged between 0.29 to 1.07cmol/kg and the SAR ranged between 0.13 and 0.72.

Interpretation

The pH readings across the eight sectors in both water and salt were all within the slightly acid (pH in salt) to very slightly acid (pH in water). The EC values are very much within safe limit, much lower than the 4dS/m prescribed for alkaline and salt affected soils (Landon, 1991). This corroborates the pH values further.

The lack of carbonate in the soil and the low (for sectors 1, 2, 3, 4, 7 and 8) to very low (for sectors 5 and 6) concentrations of the bicarbonate further supports the acidity in the soil because it implies that most of the dissolved carbon dioxide and carbonates must have been reduced to either carbonic acid (H_2CO_3) or in the transitional state of bicarbonate. The low sodium (for sectors 1, 2, 3, 4 and 5) to medium (for sectors 6, 7 and 8) concentrations and a variable concentration of Chloride with sectors 1, 2, 3, 4, 7 and 8 having low and sectors 5 and 6 having very low concentrations. There was seemingly a fall in sodium concentration in areas with high chloride ions and a high sodium concentration in areas with low chloride ions; except in sector 7 which seems to have appreciably high concentrations of both. The probable explanation for this condition may be the fact that due to the slightly acid nature of the soil, sodium ions may have been solubilised as carbonates and bicarbonates and leached out of the soil, which explains the low SAR value in all the sectors except sector 7, which has highest amounts of sodium. It also further supports the low EC values across most of the sectors. The higher chloride ions could have originated from the use of chlorinated pesticides and agrochemicals, which are not uncommon in irrigated areas under cultivation year round.

Management Implication

As an area of land under irrigation, the parameters measured in relation to salinity have indicated a soil that is far from being saline or even alkaline. The slightly acid nature of the soil 5will enhance the availability of nutrients and as shown above may further facilitate the solubilisation of sodium ions which are the primary agents of salinization and alkalinisation in irrigated soils(Alhasan,1996).

Caution should however be exercised over the results shown here because of the delicate balance that exists between different soil properties. For example, the sandy textured nature of the soil as shown above may necessitate higher irrigation frequency which in semi-arid climate like the area under study may not be desirable because of the tendency of excessive evaporation which may precipitate salts on the surface of the soil and which may be disadvantageous to non-tolerant varieties. Furthermore, the tendency for chloride build up in the soil, especially in sector 7 where the sodium concentration is equally appreciable may, in addition to the probability of chloride ions approaching toxic levels, also lead to further salt formation, even in those sectors where the sodium ions are not very high.

There is also the added fear of pH falling further low for reasons associated with nitrogen forms in the soil as will be explained in the next section. When this happens, the tendency for exchangeable bases' concentration to fall and that of micro-nutrients such as Cl and Fe to rise may not be ruled out, and these will cause nutritional complications for crops being grown in the sectors.

Irrigation, fertilizer and agrochemicals management, as well as close monitoring of soil and water conditions should be adopted as strategies to maintain and/or improve the salinity status of the sectors. Extension should focus on water use efficiency, soil conservation practices such as incorporation of organic residues and conservation tillage practices.

Table 3. Soil Fertility Status of the Watari Irrigation Scheme

Sector	*pH in H_2O*	*pH in $CaCl_2$*	*EC (dS/m)*	*CO_3^{2-} (cmol/kg)*	*HCO_3^- (cmol/kg)*	*Cl^- (cmol/kg)*	*Na^+ (cmol/kg)*	*SAR*
1	6.35	5.95	0.20	0.00	0.68	1.05	0.29	0.17
2	6.13	5.50	0.17	0.00	1.30	1.13	0.36	0.23
3	6.50	5.90	0.06	0.00	0.70	1.00	0.20	0.13
4	6.48	5.85	0.09	0.00	0.85	1.33	0.28	0.19
5	6.28	5.78	0.06	0.00	0.60	0.48	0.32	0.22
6	6.48	5.93	0.12	0.00	0.49	0.53	0.72	0.49
7	6.45	5.88	0.18	0.00	0.83	0.80	1.07	0.72
8	6.48	5.88	0.23	0.00	1.00	1.08	0.59	0.37

Source: Lab. analytical data, 2011

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The assessment of the fertility status of the soils of the Watari Irrigation Scheme was based on the parameters whose means are shown in Table 3. Organic carbon was used as indicator of organic matter content in the soil, and total nitrogen was further fractionated into ammonium and nitrate forms due to the implication of each to the soil and water. The CEC of the soils was determined and the concentrations of exchangeable bases was also determined as indicators of percent base saturation (PBS), being a more important fertility indicator than the total CEC.

The results shown in Table 4 indicate the mean organic carbon across the sectors to range between 0.62 to 1.42%. Total nitrogen ranged between 0.035 to 0.084% while the NH_4^+ and NO_3^- forms of N ranged between 0.0043 to 0.0065cmol/kg and 0.0025 to 0.0065mg/kg respectively. The range of available P was between 10.20 to 52.94mg/kg.

The CEC ranged between 9.04 to 12.68cmol/kg and the ranges for the exchangeable bases were 3.13 to 4.25; 1.06 to 1.73 and 1.28 to 2.08cmol/kg for Ca, Mg and K respectively. The Boron content in the soil across the sectors ranged between 4.09 to 6.34mg/kg.

Interpretation

The mean organic carbon content in most of the sectors could be considered as low because only sector 2 and sector 7 have their mean within the medium range. Generally values <1% are regarded as low and 1 – 1.5% are regarded as medium (Adamu, 1997). The direct implication of this low organic carbon content in the soil is that organic matter is also low. This is not unexpected in tropical environments because generally addition of organic residues which determines the organic matter content in the soil is low and their lost through mineralization is high (Binns e tal, 2003).

In contrast however, the N content of all of the sectors were high because the range considered as high starts from 0.02% or 0.03% in extreme cases (Landon, 1991). Most of the N is however in the ammonium form as can be observed in Table 3. The high N content, despite the low levels of organic matter across the sectors indicate the probable effect of application of N-fertilizer especially the ammonium forms which explains the higher concentration of its form in soil as indicated by the result. The effect of the clay content and the little organic matter in the soils could be seen, especially in sector 2, in terms of retention of the ammonium form of nitrogen. The conditions of the soil favour the retention of this form of N and the loss of the nitrate form through leaching. This also significantly relates to the pH of the soil because ammonium N is associated with acidification of soils.

The available P content for most of the sectors was within the medium range, except in sectors 5 and 7 were it is low.

The P content in the soil is also another factor that disagreed with the organic matter content of the soil (Adamu and Dawaki 2008). That is with low organic matter in the soil, the N and P may likely be low because mineralization of organic matter is known to significantly contribute to the concentrations of both. The most probable explanation for this deviation may also be attributed to fertilizer use, and in the case of the phosphorus, the mild pH might have significantly favoured its solubility from the various pools in the soils.

The CEC values in all the sectors could be regarded as medium despite the apparent variability from sector to sector which is not unexpected giving the nature of the soils especially in terms of clay and organic matter content which are the principal determinants of CEC. The soil CEC must have been significantly contributed to by the clay content, because of the poor state of the soil in terms of organic matter (Alhasan, 1996).

The Ca values across all the sectors are generally low because values of 5cmol/kg and below are generally considered low (Landon, 1991). The Ca values have slightly deviated from the fairly moderate to high values generally found in soils under irrigation. The low values recorded here are as result of the slightly acidic pH, because soils with pH values within the range of neutral to slightly alkaline are associated with high values. Furthermore, the sandy textured nature of the soils and the need for frequent irrigation encourages its leaching, which explains its deviation from the assertion of its accumulation in arid and semi-arid environments.

The Mg values are however within the medium range across all the sectors. The K values are however fairly high. The high amount of K in the soil may have also contributed to the low Ca and Mg values because of its better competitive ability for exchange sites, although their values are not however extremely bad (Foloronsho,1998). Both Ca and Mg are hovering above the Na concentration the advantage of which is their effect in lowering the SAR values as shown in Table 2. This may significantly offset the salinity condition in the soil.

The theory of the CEC being contributed to by the clay content is further validated by the amounts of basic cat ions held in the exchange complex, which has translated into a very good index of percent base saturation (PBS) (Alhasn,1996). The fact that all of the sectors have their PBS above 50% is an indicator of fertile soil only if the all the cat ions are within the medium to high range.

The boron condition in the soil is also mild. The major fear in the concentration of boron in irrigated soils is its toxicity in some crop varieties when it exceeds the maximum tolerable range (Floronsho, 1998). This is why it is always one of the parameters being evaluated in irrigation water as well as the soil.

Management Implication

The result is indicative of only marginally fertile soil. This is not unexpected in areas under continuous cultivation. Fertility decline in those types of soils is accelerated with high loss of organic matter and insufficient fertilization (Young, 1976).

Table 4. Soil Fertility Status of the Watari Irrigation Scheme

OC%	*TN%*	*AP mg/kg*	*Ca cmol/kg*	*Mg cmol/kg*	*K cmol/kg*	*CEC cmol/kg*	*B mg/kg*	*$NH4^+$ N cmol/kg*	*NO_3^- N mg/kg*
0.76	0.06	52.94	4.25	1.73	2.08	12.6775	5.34	0.007	0.006
1.43	0.08	42.66	3.43	1.37	1.64	10.2475	5.58	0.005	0.005
0.63	0.04	32.38	3.73	1.30	1.56	10.435	5.29	0.005	0.004
0.62	0.04	23.63	3.13	1.09	1.30	9.035	5.00	0.005	0.005
0.63	0.05	11.81	3.40	1.07	1.28	9.5275	4.09	0.005	0.004
0.75	0.05	24.06	3.28	1.06	1.28	9.8475	4.66	0.004	0.003
1.02	0.05	10.50	3.18	1.22	1.46	10.23	4.85	0.005	0.004
0.52	0.04	36.75	3.80	1.37	1.65	11.4	6.34	0.007	0.006

Source: Lab. analytical data, 2011

Apart from phosphorus and potassium whose values in many of the sectors are medium to high respectively, either low or just marginally above the low values for virtually all the

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indices of fertility were recorded. The major implication of this is the tendency for crops grown to exhibit deficiency if not properly fertilized, especially with nitrogen fertilizer. Fertilizer application should however follow agronomic recommendations based on crops' needs and the physico-chemical properties of the soil. For example, it is shown above that a larger concentration of the soil N is in ammonium form and with further increase; there is the tendency for the mild pH to fall further low, thereby affecting the balances of other nutrients.

As already mentioned, the soils of all the sectors would definitely benefit from addition of organic matter, with its advantage of slow release of nutrients, especially nitrogen and phosphorus.

CONCLUSION AND RECOMMENDATION

Going by these results, it is evidently clear that the soils in all the eight sectors have sand dominated texture. Furthermore, sandy textured soils are prone to erosion because of the low silt and clay contents which play very important role in binding particles and creating stable structures that can resist erosive factors such as wind and water (Adamu, 1997).

As an area of land under irrigation, the parameters measured in relation to salinity have indicated a soil that is far from being saline or even alkaline. On the orther hand, soil fertility related parameters measured are within low to medium levels.

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