International Journal of Scientific & Engineering Research, Volume 6, Issue N2Ì×ÛÌÔÉÌÛ -2015
ISSN 2229-5518

Influence of irrigation water quality on soil salinization in semi-arid areas: A case study of Makutopora, Dodoma-Tanzania.

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Abstract: This research was carried out in Dodoma, at Makutopora Agricultural Research Institute. The main objective was to determine the influence of irrigation water on soil salinization in semi-arid areas. A total of 80 representative soil samples were randomly collected from study area. Two water samples were also collected from the study area. The samples were treated and analyzed for physical and chemical related indices. The results are grouped into general quality parameters, which included salinity and salt inducing cations and anions. The findings indicated that the mean pH was 7.53 while the mean EC value was 944.5 µS/cm. The mean cations in the water were 3.97, 4.32, 2.57, and 11.39 meq/l for Ca2+, Mg2+, K+, and Na+, respectively. The Sodium Adsorption Ratio (SAR) was 5.60. The mean carbonates concentration detected in the irrigation water was 9.05 meq/l, while the mean chloride and sulfide were 17.20 and 3.6 meq/l, respectively. Soil samples were grouped into three major groups namely non-irrigated, half irrigated, and full irrigated soils. For the non-irrigated, half irrigated, and full irrigated soils: the mean pH in the soil was 6.59, 6.89 and 7.04, respectively; the mean ECe were 94.35, 338.5, and 344.72, mS/cm, respectively; SAR was 0.76, 2.64, and 4.82, respectively; exchangeable cations and anions as shown in Table 4, 6 and 8. The results reveal that water may have the potential to be hazardous to the soil as well as to the crop grown because most parameters were above safe limits. The linear regression model showed high correlation of soil salinity with exchangeable bases with R2 =0.776 and significant at p≤0.04 for non-irrigated soil, R2=0.627 at p≤0.001 for half irrigated soil, and R2=0.597 at p≤0.003 for full irrigated soil. For all soil samples the linear regression model shows strong relationships that exist between the soil salinity and exchangeable bases present in the soil. It is recommended that adequate drainage with emphasis on surface drainage should be provided and salt and sodium build up should be monitored regularly.

Key words—Irrigation water quality, soil salinization, soil physical and chemical characteristics, semi-arid, Tanzania.

1. INTRODUCTION

THE task of providing food supply to the increasing world's population is the main challenge facing sustainable agricultural development in the world today. Conversely land degradation and desertification are considered to be the main threat to sustainable agricultural development, especially in arid and semi-arid regions. Soil salinization is an important worldwide environmental problem and poses a great threat to the development of sustainable agriculture, especially in arid and semi-arid regions [1], [2]. Estimates of world salt affected soils differ; however, general estimates are close to 1billion hectares. In addition to these naturally salt affected, around 77 million hectares have been salinized as a consequence of human activities (secondary salinization). These areas on average represent 20% of the world's irrigated land, whereas these figures in arid and semi-arid countries increase more than 30% [3]. According to De Pauw [4], soil salinization in Tanzania accounts about 3.6 million hectares and it is extensive in areas with arid and semi-arid climates.

Water is a scarce resource and its supplies are threatening the sustainability of agricultural production in semi-arid parts of Tanzania such as Dodoma region. The little groundwater supply available is essentially optimized through drip irrigation, which is used to irrigate high value cash and food crops in this region. However Saline irrigation water and saline and sodic soils are threats to irrigated agriculture due to accumulation of salts in the soil. Climate change predictions of increase in temperature and decrease in rainfall imply that water is becoming even scarcer. As it is the case in this region of Dodoma where frequent droughts and restricted supply of good quality water is the most important factor limiting crop production. The shortage of freshwater has become fundamental and chronic problem for sustainable agricultural development in arid and semi-arid regions. Meanwhile the quantity of

International Journal of Scientific & Engineering Research, Volume 6, Issue
ISSN 2229-5518

irrigation water has deteriorated making saline water a valuable alternative water source for irrigation [5]. Irrigation with saline water has become inevitable in arid and semi-arid regions [6]. However the use of saline water increases the risk of soil salinization due to salt accumulation in the root zone [7]. When saline water is used for irrigation, increases in the amount of water and in the frequency of irrigation are both needed to prevent the salt accumulation [8]. Hence, efficient use of saline water by irrigation is becoming increasingly important, and alternative water application method such as drip may contribute substantially to attain the twin objectives of higher productivity and optimum use of water. Therefore, the main objective of this research work was to determine the influence of irrigation water quality on soil salinization in semi-arid Makutopora area in Dodoma, Tanzania.

2. MATERIALS AND METHODS

2.1. The Study Area

2.1.1. Location

The study was conducted in 2014 at Makutopora Agricultural Research Institute located in Dodoma region in the Makutopora basin (Latitude: 5o36’59’’ and 6o14’50’’S, Longitude: 35o36’36’’ and 36o01’54’’E, at an altitude of 1080m a.s.l), during the dry season. The Makutopora depression and its surroundings have an area of 120 km2.

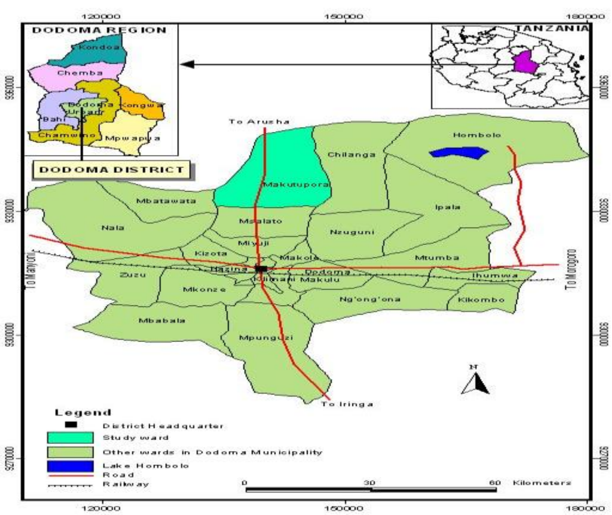

Figure 1: Location map for the research area

2.2. Methodology

2.1.2. Climate condition

Dodoma region has the unimodal type of rainfall mostly from November to April with an average annual rainfall of 550mm. There is virtually no rainfall from May to October [9]. The monthly maximum temperature is 26oC while monthly minimum is 21oC. The minimum temperature occurs around July while the maximum temperature occurs around February and it starts to rise in August while it gets to its peak in February.

Radiation governs the rate of evaporation. In the study area there is a monthly maximum radiation value of 25 MJm-2 while the minimum is around 19.5 MJm-2. The wind speed varies from 1.67ms-1 to around 4ms-1. The maximum wind speed occurs during the dry season and decrease during the rainy season.

2.1.3. Topography and soil conditions

The topography is dominated by inselbergs and pediment plains underlain by Precambrian basement rocks and basin floor. In the area three main features can be distinguished: mountains and hills, upland and lowlands. The soil types in the study area are red loamy soil and black clayey soil. The dominant soil type is the red loam soil distributed in the upper and lower plateau with many termite mounds [10]. Black soils cover the seasonal water logged swampy areas while red loam soils are distributed on the hilly slope of basic rocks such as biotite, gneiss and dolerite dykes [11].

2.1.4. Drainage system

Drainage within the mountain range is controlled by the NW and NE trending faults or shear zones. There are no perennial rivers while ephemeral rivers flow only after heavy rain storms during rainy season [11]. Little Kinyasungwe is the main river in the area originating from NE part of the catchment. Its first part flows in the SW direction and forms a swamp at Makutopora basin. After forming a swamp the river discharges to the Hombolo dam which is located SE of the basin.

2.2.1. Soil samples collection

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The soil samples were collected from designated locations within the experimental plots. A total of 30 soil samples were collected from three experimental plots that grew pearl millet, sunflower and rice (Nerica-4 variety), which received full irrigation and referred as full irrigation plots. Thirty (30) soil samples were collected from the other experimental plots that grew pearl millet, sunflower and rice from the plots with 50% irrigation requirements and referred to as half-irrigation plots. Sixteen (16) soil samples were collected from non-irrigated area within the same farm as a control for comparing their salinities, soil pH, cations, anions and Sodium Adsorption Ratio. The soil samples for determination of physical properties were collected from the profile pit dug up to 1m using soil core sampler. The composite soil samples were collected from different parts of the respective plot at a depth of 5 cm and thoroughly mixed up. All samples were taken to the laboratory for preparation and analyses.

2.2.2. Water sample collection

Irrigation water samples were collected for two times (October, 2014 and June, 2015) from the irrigation reservoir at the experimental site using 1.5litre plastic bottle that was cleaned three times using the same water and taken for laboratory analysis.

2.2.3. Laboratory analysis

All samples were made a half of kilogram according to Richard [12] for each and were taken for laboratory analyses. Standard laboratory methods for determining electrical conductivity of saturation extract (ECe), soil pH, cations, and anions were employed. The soil texture and particle size distribution were determined using Bouyouscos method [13], popularly known as hydrometer method. The water holding capacity was determined using rudimentary method. The pH in H2O was determined using pH meter [14]. The measured concentrations of ECe and Exchangeable bases were extracted using ammonium acetate extraction technique and determined by flame photometry [15]. SO42- was determined by gravimetric titration, and HCO3- and CO32- by potentiometric titration method [16]. The laboratory analysis of irrigation water included water salinity (ECw), Acidity and Alkalinity (pH), Cations (Na+, Ca2+, Mg2+, and K+), anions (Cl-, SO4-, HCO3-, and CO32-), and Sodium Adsorption Ratio, and they were analyzed according to Ayers and Westcott [17].

2.2.4. Statistical Analysis of soil samples

The soil data were subjected to analysis of variance (ANOVA) using SPSS v.20. The significant differences between full irrigated, half irrigated and non-irrigated soils were determined at 0.05 level of significant.

3. RESULTS AND DISCUSSION

This chapter presents and discusses the results obtained from soil analysis such as particle size distribution, soil pH, electrical conductivity of saturation extract (soil salinity, ECe), cations, anions and Sodium Adsorption Ratio. The water quality parameters are also presented and compared with water quality standards. In addition, comparison between the results was also done. The mean values of analyzed soil parameters at the investigated area are shown in Table2-8.

3.1. Assessment of Water Quality

3.1.1. Salinity and Cations

The general quality of the irrigation water in terms of salinity and cations is assessed based on parameters shown in Table 1a. The mean values shown are for two samples taken from the reservoir next to the experimental site that receives water pumped from the main reservoir serving the whole institute. The mean pH was 7.53, while the mean EC value was 944.5mS/cm. The mean metal cations in the water were 3.97, 4.32, 2.57 and 11.39 meq/l for Ca2+, Mg2+, K+ and Na+ respectively. The mean SAR was 5.60. The anions in the water were as shown in the Table.

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ISSN 2229-5518

TABLE 1A: MEAN IRRIGATION WATER QUALITY PARAMETERS

Water pH	ECw (µS/cm)	Cl- (meq/l)	SO_4^{2-} (meq/l)	CO_3^{2-} + HCO_3^- (meq/l)	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	K^+ (meq/l)	Na^+ (meq/l)	SAR
7.53	944.5	17.20	3.60	9.05	3.97	4.32	2.57	11.39	5.60

TABLE 1B: GUIDELINES FOR EVALUATING IRRIGATION WATER QUALITY

Potential irrigation problem		Degree of restriction on use		
	Uinits	None	Slight to moderate	Severe
Electric conductivity, ECw	dSm-1	<0.7	0.7-3.0	>3.0
Sodium in terms of SAR		<3.0	3.0-9.0	>9.0
Chloride	meql-1	<4.0	4.0-10.0	>10.0
Bicarbonate	meql-1	<1.5	1.5-8.5	>8.5
pH		Normal range 6.5-8.4		

Source: Adapted from California Committee of Consultants (1974), quoted in Landon (1991)

a) Interpretation

Generally pH values for normal irrigation water should be between 6.00 and 7.00, while values above 7.00 are considered as of increasing hazard [18]. This characteristic of the water has a significant influence on other characteristics or reactions in the soil and water, as well as the way plants perform.

The concentration of total salt content in irrigation waters is estimated in terms of ECe and it may be the most important parameter for assessing the suitability of irrigation waters [19], [20]. It gives an estimate of the total amounts of dissolved salts in the water and the total amount and kinds of salts determine the suitability of the water for irrigation use [19]. Generally, the ranges considered for irrigation water suitability are 20 to 70, 70 to 300 and > 300 µS/cm being normal, increasingly severe and severe with respect to salinity hazards [21]. From this perspective, the irrigation water best described as being severe and poses an immediate threat to soil salinization, as the mean ECe observed was above the normal range. The higher mean ECe value for irrigation water further corroborates the high values in the soil which also rises much higher as noted in half irrigated soils and full irrigated soil as compared to non-irrigated soil.

The amount of Na ions in the water predicts the sodicity danger of the water [22]. Sodium ions are important criteria for irrigation water quality because of its effect on soil permeability and water infiltration [20]. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. Sodium ions cause deflocculation of particles and subsequent sealing of soil pores thereby preventing water passage into the soil. Sodic water causes excess Na to be adsorbed to exchange complex and in the process causes dispersion of

International Journal of Scientific & Engineering Research, Volume 6, Issue [illegible]
ISSN 2229-5518

aggregates and thereby blocking pores in the soil and preventing or reducing infiltration of applied water. Generally, values greater than 0.4meq/l in terms of Na concentrations are regarded as posing increasing severity of sodicity especially in soils high in clay content [23]. The value recorded in the irrigation water may therefore be interpreted as posing severe risk factor of sodium toxicity to the soil. The apparent effect as shown by the EC values may be as a result of the fact that the soil is also high in clay content which is the principal particle that deflocculates in the presence of excess sodium. The SAR relates the relative concentration of Na to the combined concentrations of Ca and Mg ions [24]. Increasing sodicity hazards may be associated with values exceeding 6. As SAR is a factor of sodium against calcium and magnesium, the high values recorded may not be a surprise as the sodium values are also relatively high. These further elaborate the risk factor associated with this irrigation water.

The normal range of Ca^{2+} in irrigation water should be 0 – 1.0meq/l, while that of Mg^{2+} should be between 0 – 0.2meq/l [25]. By these criteria the calcium content of irrigation water could be described as being above the safe limit. This also applies to the magnesium content which is above the recommended mean. The relatively higher amounts of magnesium compared to the calcium may be bad because Mg deteriorates soil structure particularly where waters are sodium-dominated (as is the case with the irrigation water assessed) and highly saline. The reason for this structural degradation is that high level of Mg usually promotes a higher development of exchangeable Na in irrigated soils and the negative effect of high sodium content in soil is as described above. The Magnesium content of water is also considered as important qualitative criteria in determining the quality of water for irrigation because more magnesium in water will adversely affect crop yields, as the soils become more alkaline. Generally, calcium and magnesium maintain a state of equilibrium in most waters [25]. The combined effect of these two ions is in their countering the negative effect of the sodium by lowering the SAR as shown above.

The presence of potassium ions in excessive amounts does not constitute any risk and may even supplement crops' needs as only values exceeding 1.3meq/l may be considered as posing any serious risk factor with irrigation water.

b) Management implication

The results reveal that water may have the potential to be hazardous to the soil as well as to the crop grown, because the two most important parameters used in assessing the safety of irrigation water; namely, Water salinity (ECw), Sodium ions and the associated SAR are above the safe limits. The implication of these high values is that there is the tendency for the soil to be saline and therefore what are recommended here may be measures aimed at mitigating the development of saline or sodic soil. The following measures are worthy of note and implementation singly or in combination.

1. Provision of adequate drainage ditches with emphasis on surface drainage during the rain season, as the textural property of the soil indicates soil with potency for good internal drainage.

2. Provision should be made for use of irrigation water to meet the necessary leaching requirement over- irrigation. This is necessary to avoid build-up of salts in the soil solution to levels that will limit crop yields. Effective rainfall can be considered part of the leaching requirement by constructing drainage ditches to drain salts during the rain season.

3. The soil should be maintained at high available moisture level (always moist and not soaked) and should not be allowed to become more than moderately dry, since the crop cannot remove all the normally available water due to the higher salt content.

4. Salt and sodium build up should be monitored regularly (every 1 to 2 years). Development of a sodium hazard usually takes time and therefore soil tests for SAR or percent exchangeable sodium can detect changes before permanent damage occurs. Soil samples to be analyzed should represent the top soil and occasionally the sub soil.

5. Soluble calcium such as gypsum should be added to decrease the SAR to a safe value. The gypsum can be dissolved into the water or it can be broadcasted over the field. It should be broadcasted directly before irrigation or thoroughly incorporate into the tillage layer to avoid crusting problems.

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3.1.2. Anions

The quality of the irrigation water in terms of anions is as shown in Table 8. The mean carbonates and bicarbonate concentration detected in the irrigation water was 9.05meq/l, while the mean chloride content was 17.2meq/l. The sulfate detected was 3.60meq/l.

a) Interpretation

The normal safe ranking for carbonate (CO32-) and bicarbonates (HCO3-) are 0.03 and 0.16meq/l respectively [24]. By this criteria therefore, the irrigation water could be described as being at severe risk with regards to carbonates and bicarbonates. High carbonate and bicarbonate in water essentially increases the sodium hazard of the water to a level greater than that indicated by the SAR. High CO32- and HCO3- tend to precipitate calcium carbonate (CaCO3) and magnesium carbonate (MgCO3), when the soil solution concentrates during soil drying. If the concentrations of calcium and magnesium in soil solution are reduced relative to sodium the SAR of the soil solution tends to increase as stated above. Another effect of carbonates and bicarbonates is on the alkalinity status of the soil. High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acid for some plant. Another aspect of alkalinity is its potential effect on sodium. Soil irrigated with alkaline water may, upon drying, cause an excess of available sodium. Several potential sodium problems as highlighted above could therefore result. Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. Chloride (Cl-) ions are one of the anions in irrigation water for the potential of the water for phytotoxicity. The normal and safe limit for chloride ions in irrigation water should not exceed 0.85meq/l [24] by which standard the irrigation water could be described as being at any potential risk. The influence of bicarbonate and carbonate on the suitability of water for irrigation purpose is empirically assessed based on the assumption that all Ca2+ and Mg2+ precipitate as carbonate [26].

b) Management Implications

High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3cmol/l will cause lime (calcium and magnesium carbonate) to be deposited on soils and even on foliage especially when irrigated with overhead sprinklers. This may be undesirable for vegetable plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging to many tree species. The most efficient corrective measure for high alkalinity is acidification of the water and the soil. This can be achieved by direct controlled acid injection in the water; or the safer major of incorporation of high levels of organic matter in the soil which on decomposition releases organic acids into the soil that solubilise sodium and prevent its accumulation in the soil [27].

3.2. Assessment of soil quality

The results of the soils analysis of the various samples for full irrigated soil, half irrigated soil and non-irrigated soil are presented in Tables 2-7. The results are grouped into ten sections soil pH, soil salinity, chlorides, sulfides, carbonate and bicarbonates, exchangeable calcium, exchangeable magnesium, exchangeable Potassium, exchangeable Sodium and Sodium Adsorption Ratio. The soil physical properties are also discussed.

3.2.1. Soil Physical Properties of Makutopora research station.

The physical condition of the soil was assessed for particle size distributions in the soil and subsequently translated into textural classes. The mean values for clay, silt and sand were as shown in the Table 2. The highest sand content was recorded at 0-10cm depth, which correspondingly also had the least content of clay and silt and classified as sandy loam soil. Soil profile 10-30cm was classified as sandy clay and the sand clay loam was observed at 30-40cm profile depth. Bulk density is dependent on soil organic matter, soil texture, the density of soil mineral (sand, silt, and clay) and their packing arrangement [12]. The upper profile had higher percentage of sandy soils with relatively high bulk density since total pore space in sands is less than silt or clay soils [12].

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a) 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 [28]. Such soils are also prone to excessive 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 efficiency 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 [29].

TABLE 2: MEAN SOIL PHYSICAL PROPERTIES

Depth	P.S.D			Texture	B.D	WP	FC	AW
cm	% Clay	% Silt	% Sand	Class	g/cm3	%volume	%volume	mm/m
0-10	13	16	71	SL	1.25	9.8	18.2	8.4
10-20	35	16	49	SC	1.20	22.1	33.6	23
20-30	35	16	49	SC	1.11	22.1	33.6	34.5
30-40	25	16	59	SCL	1.09	16.6	26.9	41.2

3.2.2. Soil salinity (ECe)

The spatial distribution of soil salinity in the soil horizons were found to be higher at shallow depths of 0-10cm and decreasing gradually up to a depth of 40cm. This trend shows that the irrigation water applied was slightly saline with higher sodium content and the quantity applied was not sufficient to leach salinity below the crop rooting zone. Therefore when the soil temperature raised some salinity and bicarbonates were pushed to the surface of the soil. The results showed that non-irrigated soils had low soil salinity as compared to half and full irrigated soils. The mean soil salinity in non-irrigated soil was 94.35mS/cm, 338.5mS/cm for half irrigated soil and 344.72mS/cm for full irrigated soil. The data showed that there was gradual increase of soil salinity in the soil that could have been aggravated by irrigation water. The linear regression model showed high correlation of soil salinity with exchangeable bases with R2 =0.776 and significant at $p \leq 0.04$ for non-irrigated soil, R2=0.627 at $p \leq 0.001$ for half irrigated soil and R2=0.597 at $p \leq 0.003$ for full irrigated soil. To all soil samples the linear regression model shows strong relationships that exist between the soil salinity and exchangeable bases present in the soil.

Soil pH increased with an increase of irrigation water; the pH recorded were 6.59, 6.76 and 7.04 for non-irrigated, half irrigated and full irrigated soils respectively. The linear regression model showed that there was strong relationship with R2= 0.862 and were significant at $p \leq 0.000$.

Sodium Adsorption Ration (SAR) in the soil were 0.76, 2.64 and 4.82 for non-irrigated, half irrigated and full irrigated soils respectively. The linear regression models for SAR with cations for all soils were R2 = 0.993 at $p \leq 0.000$, R2 = 0.965 at $p \leq 0.000$ and R2 = 0.959 at $p \leq 0.000$ for non-irrigated, half irrigated and full irrigated soils respectively.

a) Interpretation

The pH readings across the soil profile depth were neutral (pH in H2O) to slightly alkaline for both full and half irrigated soil while the pH value for non-irrigated soil in the profile ranged from moderately acidic to neutral. The ECe values were very much higher than the safe limit, much higher than the 4dS/m describing the soil as being slightly alkaline and salt affected [24]. This corroborates the pH values further. The presence of higher concentrations carbonates and bicarbonates in the soil further supports the

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ISSN 2229-5518

alkalinity in the soil because it implies that most of the dissolved carbon dioxide and carbonates must have been increased to either carbonic acid (H2CO3) or in the transitional state of bicarbonate. The higher sodium concentrations and higher concentration of Chloride makes the salinity in the soil to be in a form of sodium chloride (Nacl2).

The Ca2+ values across soil profile are generally higher because values greater than 20ppm are generally considered high [24]. The higher values recorded here are as a result of slightly alkaline pH, because soils with pH values within the range of neutral to slightly alkaline are associated with high values of exchangeable calcium. However, 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 Mg2+ values are however within the medium range across the soil profile, values greater than 30-60ppm are usually low-moderately sufficient in soil, according to Landon [24] the Mg2+ uptake may be affected by high exchangeable Potassium level.

The K+ values are however fairly high. The high amount of K+ in the soil may have also contributed to the low Ca2+ and Mg2+ values because of its better competitive ability for exchange sites, although their values are not extremely bad [30]. Both Ca2+ and Mg2+ are hovering above the Na+ concentration the advantage of which is their effect in lowering the SAR values. This may significantly offset the salinity condition in the soil.

b) Management Implication

As an area of land under irrigation, the parameters measured in relation to salinity have indicated a soil that is becoming saline or even alkaline. The slightly alkaline nature of the soil will not enhance the availability of nutrients and may further facilitate the solubilisation of sodium ions which are the primary agents of salinization and alkalinisation in irrigated soils [31]. 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 may cause chloride ions approaching toxic levels, also lead to further salt formation. 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 soil. Extension should focus on water use efficiency, soil conservation practices such as incorporation of organic residues and conservation tillage practices.

TABLE 3: SPATIAL DISTRIBUTION OF SOIL CHEMICAL PROPERTIES WITH DEPTHS IN FULL IRRIGATED

Depth (cm)	Soil pH(in H2O)	ECe (mS/cm)	CL- (mg/kg)	SO42-- S(mg/kg)	CO32- +HCO3- (mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
5	7.51	498.50	344.06	100.55	71.17	262.98	60.77	441.22	486.42	6.65
0-10	7.59	364.80	175.72	78.85	122.00	235.01	21.14	104.54	261.38	4.64
10-20	7.17	302.00	149.14	44.94	64.81	165.06	23.05	128.30	252.58	4.92
20-30	6.58	302.68	212.64	62.18	72.44	207.03	36.27	156.40	380.66	5.67
30-40	6.35	255.60	121.09	44.51	59.73	158.07	23.76	179.85	108.45	2.22

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ISSN 2229-5518

TABLE 4: SOIL CHEMICAL PROPERTIES FOR FULL IRRIGATED SOILS

	pH(in H2O)	ECe (mS/cm)	Cl- (mg/kg)	SO42--S(mg/kg)	CO32-+HCO3-(mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
Mean	7.04	344.72	200.53	66.21	78.03	205.63	33.00	202.06	297.90	4.82
Std. Deviation	0.92	190.45	189.66	59.09	41.41	114.61	29.45	252.75	307.22	3.53
Cv	13.03	55.25	94.58	89.25	53.07	55.74	89.26	125.08	103.13	73.36
Number of sample	30	30	30	30	30	30	30	30	30	30

TABLE 5: SPATIAL DISTRIBUTION OF SOIL CHEMICAL PROPERTIES WITH DEPTHS IN HALF IRRIGATED SOIL

Depth (cm)	Soil pH(in H2O)	ECe (mS/cm)	CL- (mg/kg)	SO42--S(mg/kg)	CO32-+HCO3-(mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
5	7.50	899.67	471.06	116.64	79.40	549.75	111.80	818.86	542.39	5.62
0-10	7.36	327.93	135.85	34.45	66.08	193.04	24.97	319.03	154.72	2.88
10-20	6.77	218.20	136.59	47.53	63.54	186.05	18.31	196.60	139.28	2.76
20-30	6.18	129.02	94.51	26.26	50.83	193.04	19.63	166.23	54.56	1.02
30-40	5.98	117.80	76.79	37.90	62.27	172.06	17.61	170.97	48.64	0.93

TABLE 6: SOIL CHEMICAL PROPERTIES FOR HALF IRRIGATED SOILS

	pH	ECe (mS/cm)	Cl- (mg/kg)	SO42--S (mg/kg)	CO32-+HCO3-(mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
Mean	6.76	338.52	182.96	52.56	64.43	258.79	38.46	334.34	187.92	2.64
Std. Deviation	0.86	396.90	209.49	53.61	53.61	216.99	56.36	455.58	229.15	2.47
Cv	12.76	117.24	114.50	102.01	83.22	83.85	146.52	136.26	121.94	93.57
Number of sample	30	30	30	30	30	30	30	30	30	30

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TABLE 7: SPATIAL DISTRIBUTION OF SOIL CHEMICAL PROPERTIES WITH DEPTHS IN NON- IRRIGATED SOIL

Depth (cm)	Soil pH(in H2O)	ECe (mS/cm)	Cl- (mg/kg)	SO42-- S(mg/kg)	CO32- +HCO3- (mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
0-10	6.89	101.73	62.02	40.56	53.38	151.08	13.07	255.64	20.34	0.43
10-20	6.95	101.85	55.38	18.36	53.38	193.04	23.51	166.31	36.89	0.67
20-30	6.74	79.00	73.10	31.08	78.16	182.55	16.10	138.35	30.65	0.59
30-40	5.80	94.83	55.38	22.67	57.19	151.08	16.40	91.82	65.19	1.35

TABLE 8: SOIL CHEMICAL PROPERTIES FOR NON-IRRIGATED SOILS

	pH(in H2O)	ECe (mS/cm)	Cl- (mg/kg)	SO42-- S(mg/kg)	CO32- +HCO3- (mg/kg)	Ca2+ (ppm)	Mg2+ (ppm)	K+ (ppm)	Na+ (ppm)	SAR
Mean	6.59	94.35	61.42	28.17	60.52	169.44	17.27	163.03	38.27	0.76
Std.Deviation	0.49	14.75	21.08	22.01	31.19	37.44	6.38	66.44	17.64	0.37
Cv	7.44	15.63	34.32	78.13	51.54	22.10	36.94	40.75	46.09	48.68
Number of sample	16	16	16	16	16	16	16	16	16	16

4. CONCLUSION

Higher values of pH, ECe, carbonates and bicarbonates, Chloride and exchangeable sodium observed in the soil for full irrigation and half irrigation relative to those noted in non- irrigated soil indicates that there is accumulation of salinity in the soil that could have been aggravated by the slightly saline irrigation water with high chloride and exceeding sodium contents. The regression analysis done shows that there is high relationship between the soil salinity and cations present.

5. RECOMMENDATIONS

Soluble calcium such as gypsum should be added in irrigated water to decrease the SAR to a safe value. The gypsum can be dissolved into the water or it can be broadcasted over the field. It should be broadcasted directly before irrigation or thoroughly incorporate into the tillage layer to avoid crusting problems.

Salt and sodium build up should be monitored regularly (every 1 to 2 years). Development of a sodium hazard usually takes time and therefore soil tests for SAR can detect changes before permanent damage occurs. Soil samples to be analyzed should represent the top soil and occasionally the sub soil.

Further studies needs to be conducted for determination of leaching requirements for the given water and soil qualities.

Construction of drainage ditches for draining excess salts during the rainfall period.

ACKNOWLEDGEMENT

This review was made possible through financial support provided by Trans-SEC-Project. The support is highly appreciated.

International Journal of Scientific & Engineering Research, Volume 6, Issue ƝǐϮÌ×ÛÌÔÉÌÙƖǇƙ
ISSN 2229-5518

REFERENCE

[1] M.M. Jordán, J. Navarro-Pedreño, E. García-Sanchez, J.Mateu and P.Juan, "Spatial dynamics of soil salinity under arid and semi-arid conditions", Environmental geology, vol.45, no.4, pp.448-456, 2003.

[2] Y. Wang, Xiao, Y.Li, and X. Li, "Soil salinity evaluation and its relationships with dynamics of groundwater in the Oasis of inland river basins", Case study from the Fubei region of Xinjiang province, China, Environmental monitoring and assessment vol.140, pp.291-302, 2008.

[3] M.A. Abdel-Hamid and D.P. Shrestha, "Soil salinization mapping in the Nile Delta". Egyptusing remote sensing using techniques, International achieves of photogrammetry and remote sensing, ISPRS Commission VII/4, Washington D.C, vol. 29, no.B7, pp.783-787, 1992.

[4] E.De Puaw, "Development of land use planning and land tenure in Tanzania Main Report", Technical Support Services Project, TSS1–URT/94/02T, Tanzania, 1994.

[5] [5] J.Jiang, Z.Huo and S. Feng, "Effect of irrigation amount and water salinity on water consumption and water productivity of spring wheat in Northwest China", Field Crops Research, vol.137, pp.78-88, 2012.

[6] J. Letey and G .L. Feng, "Dynamic versus steady-state approaches to evaluate irrigation management of saline waters". Agricultural Water Management. Vol.91, pp.1-10, 2007.

[7] L. S.Pereira, T.Oweis and A. Zairi, Irrigation management under water scarcity. Agric. Water Manage., vol.57, no.3, pp.175-206,2002.

[8] D. L. Corwin, J. D. Rhoades, and J.Simunek, "Leaching requirement for soil salinity control", Steady-state versus transient models, Agricultural Water Management. Vol.90, pp.165-180, 2007.

[9] K.Sandstrom, "Modeling the effect of rainfall variability on groundwater recharge in semi-arid Tanzania". International Journal Nordic Association for Hydrology, vol.26, pp.313-330, 1995.

[10] S.Shindo, "Study on the recharge mechanism and development of groundwater in the inland area of Tanzania", Progress report of Japan-Tanzania joint research-1, Chiba University, Chiba, (Ed), 1989.

[11] S. Hamza, "Hydrological study of Makutopora basin Dodoma Tanzania", supported by ground water flow modeling, ITC, Enschede, 1993.

[12] L.A. Richard (Ed), "Diagnosis and Improvement of saline and alkali soil", U. S. Salinity Laboratory Staff, Agricultural Handbook no. 60.United State Dept. of Agriculture, US Government printing office, Washington DC, 1954.

[13] G.J.Bouyouscos, "Hydrometer method improved for making particle size analyses of soils", Agron. J., vol.54, pp.464-465, 1962.

[14] J.P.Moberg, "Revised Edition of Soil Analysis Manual", Soil Science Department, Sokoine University of Agriculture, pp.137, 2001.

[15] J.A. Adepetu, H. Nabhan and A. Osinubu, "Simple soil, water and plant testing techniques for soil resources management, proceedings of a training course held in Ibadan, Nigeria, 16-27September 1996, Ibadan, IITA, pp.168, 2000.

[16] FAO, "Physical and Chemical Methods of Soil and Water Analysis", Rome, vol.30, pp.208, 1980.

[17] R.S. Ayers and D.W.Westcott, "Water Quality for Agriculture", Irrigation and drainage, paper 29, Rev 1, Food and Agriculture Organization, Rome, 1985.

[18] M.M. Danko, "Comparative analysis of variables of irrigation water quality along river Rima", B. Agricultural project, Department of soil science and Agricultural engineering, Usman Dan Fodio Sokoto, pp.45, 1997.

[19] F. I. Belan," Water treatment", Mir Publishers Moscow, USSR, pp.232, 1985.

[20] F.Ajayi, M. Nduru and A. Oningue, "Halting the salt that kills crops", African Farmer, no.4, pp.10-12, 1990.

[21] P. J., D. Shoeneberger, A. Wysocki, E. C. Benham and W.D. Broderson, "Field Book for Describing and Sampling soils", Version 2.0 National soil Survey Center, National Resources Conservation Services, U. S. Department of Agriculture, Lincoln. (Ed), 2002.

[22] B. R.Singah, "Quality of irrigation water in Fadama lands North-western Nigeria", Ground and Surface Water in Kebbi State, Nig. J. Basic. And Apl. Sci., vol.9, pp.148, 2000.

[23] S. W. Davis, and R.J.M. Dewest, "Hydrology", John Willey and Sons, New York, pp. 463, 1966.

[24] J. R. Landon, "Booker Tropical Soil Manual", John Wiley and Sons Inc., New York, (Ed), 1991.

[25] J.E.Christenson, E.C. Olsen, and L.S. Willardson, "Irrigation water quality evaluation", Journal of irrigation and Drain. Div., A and CIR 2.proc. paper 13015, 1977.

[26] A. M. Michael, "Irrigation principles and practices", Vikas publishing house ltd, New Delhi, pp.702-720, 1985.

[27] G.K. Adamu, "Quality of irrigation water and soil characteristics of Watari irrigation project", American Journal of Engineering Research, vol.2, no.3, pp.59-68, 2013.

[28] G.K. Adamu," An assessment of erodibility of selected soils under different land management systems at Bayero University", Kano New campus, Unpublished PGD Project Soil evaluation, BUK, 1997.

[29] G. Omar, "Assessment of the Fertility Status of some Irrigated Fluvisols in Northern Guinea Savannah of

International Journal of Scientific & Engineering Research, Volume 6, Issue ꞏꞏꞏꞏ
ISSN 2229-5518

Nigeria", Department of Soil Science, Faculty of Agriculture, Bayero University, Kano, 2011.
[30] E.Foloronsho, "Evaluation of soil fertility status Under Irrigation in Jakara River Valley", A case study of Air- Port Road-Katsina Road, Kano Metropolis, Post Graduate Diploma in Land Resources Thesis, Geography department, Bayero University, Kano,1998.
[31] J.Alhasn, "Determination of CEC and exchangeable bases (Ca, Mg, K and Na) of soils from Sokoto-Rima River Basin at Kwalkwalawa", A BSc. project submitted to the department of soil science and Aric, Usman Dan Fodio University, Sokoto, 1996.

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