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Soil Quality of Irrigable Lands of Irrigation Schemes in Northern Ghana

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Abstract

This research was carried out in the Tono, Vea, Doba Libga, Bontanga and Golinga irrigation schemes in the Upper East and Northern Regions of Ghana to assess soil quality of the irrigable areas. The irrigable areas of the schemes were divided into three blocks namely; upstream, midstream and downstream for soil sampling. Three (3) composite soil samples each were taken at 0 – 30 cm depth in each stream of each scheme. The findings indicated that the pH of the soils from all the schemes except Libga were within 5.2 – 6.4, whilst the soils of Libga scheme have average pH of 8.8. Electrical conductivity or salinity in the schemes except Libga ranged from 1.2 – 39.3 µS/cm whilst the Libga scheme recorded salinity levels of 317 – 4,106 µS/cm. The mean ESP or sodicity of all the schemes except Libga ranged from 1.0 – 4.8 % with the Libga scheme recording levels of 8.5 – 30 %. Mean sodium values of the Libga scheme averaged 440.7 mg/kg whilst the other schemes recorded averages ranging from 47.3 – 71.0 mg/kg. The mean CEC concentration for the Libga scheme was 7.9 cmol/kg with the other schemes recrding between 7.9 – 19.5 cmol/kg. The irrigable areas of Tono, Vea, Doba, Bontanga and Golinga schemes were noted to be environmentally stable recording an index of 95 – 100 %. The irrigable area of Libga scheme however recorded an environmental stability index of 86 %. Excessive application of inorganic fertilizers should be avoided. The management of the schemes especially the Libga scheme should periodically and regularly monitor pH, salinity and sodicity levels in the irrigable areas.

***Keywords**: Soil quality, irrigable lands, irrigation schemes, Northern Ghana, salinity and sodicity*

1. Introduction

Irrigation is essential for world food production (Tellefson and Hogg, 2007). Throughout history, water resources and irrigation development have played a major role in human development. Most of the growth in food production needed to meet the fast population growth over the past years has resulted from an expansion of the irrigated area (Wolter and Kandiah, 1997). Modern irrigated agriculture started in Ghana in 1960s and as at 2007, about 33,800 ha of Ghana's land was under irrigation (Namara *et al.*, 2011). Irrigation development, while contributing to the economic well-being of many countries, has potential negative effects on the soil (Pereira *et al*., 1996). Bardak-Meyers (1996) argued that despite the increase food production, diversification and associated economic benefits, the sustainability of irrigation is questioned due to its detrimental effects on the soil (waterlogging, soil salinity, sodicity, nutrient deficiency, alkalinity and groundwater contamination). Binns *et al.* (2003) remarked that the continuous use of developed irrigable lands throughout the year for both irrigation and rain-fed conditions could trigger fertility depletion, salinity and sodicity. Poor quality of irrigation water affects both soil quality and crop production adversely (Bello, 2001). Regardless of the source, irrigation water contains some dissolved salts (Michael, 1985). The concentration and proportion of dissolved salts among other things determine the suitability of water for irrigation (Ajayi *et al.*, 1990; Adamu, 2013.

Waskom *et al.* (2010) indicated that accumulation of salts in soils can result in three (3) soil conditions namely; saline, sodic and saline - sodic soils. Horneck *et al.* (2007) stated that salility in soil can originate from soil parent material; from irrigation water, from fertilizers or other soil amendments. Charm and Murphy (2000) defined sodicity as the relative predominance of exchangeable sodium compared to other exchangeable cations, mainly calcium, magnesium, potassium, hydrogen and aluminium and is expressed as ESP (exchangeable sodium percentage). The sodium adsorption ratio (SAR) is another expression of sodicity that refers to the ratio of adsorbed sodium and the sum of calcium and magnesium. Soil salinity is a characteristic of soils relating to their content of water-soluble salts and expressed mostly as ECe (electrical conductivity of paste extract) and is measured as dS m^{-1}.

Horneck *et al.* (2007) reported that saline soils commonly have visible salt deposits on the surface and are sometimes called "white alkali" soils whereas sodic soils often have a black colour and are called "black alkali" or "slick spots." Saline-sodic soils are high in sodium and other salts. They typically have electrical conductivity (EC) greater than 4 dS/m (mmhos/cm), SAR greater than 13, and/or ESP greater than 15. Soil pH can be above or below 8.5. Liu and Hanlon (2012) defined soil pH as a measure of soil acidity or basicity. pH ranges from 0 - 14. A pH of 7.0 is defined as neutral, while a pH of less than 7.0 is described as acidic and a pH of greater than 7.0 is described as basic. It is one of the most important soil chemical properties and affects nutrient bioavailability and microbial activity. pH determines the solubility and bioavailability of nutrients essential for crop production.

Salinity is a serious threat to agriculture in arid and semi-arid regions (Rao and Sharma, 1995; Salehi *et al.*, 2008). Approximately 932 million ha of farmlands worldwide are degraded due to salinity and sodicity. Of this area, salinity affects 23 % of arable land while saline-sodic soils affect a further 10 % (Szabolcs, 1989; Wobong, 2006). The deleterious effects of salinity and sodicity on soil physical and chemical properties are well known, and ultimately cause declines in plant growth (Wong *et al.*, 2004). Accumulation of excessive salt in irrigated soils can reduce crop yields, reduce the effectiveness of irrigation, ruin soil structure, and affect other soil properties. Any salt that accumulates in excessive amounts in soil can cause plant growth problems. Too much sodium causes problems related to soil structure. As sodium percentage increases, so does the risk of dispersion of soil aggregates (Horneck *et al.*, 2007). Saline soils contain excess soluble salts that reduce the growth of most crops. Salinity reduces water availability for plant use as high salt levels hinder water absorption, inducing physiological drought in the plant. The soil may contain adequate water, but plant roots are unable to absorb the water due to osmotic pressure. Plants are generally most sensitive to salinity during germination and early growth (Senon *et al.*, 2012).

Sodicity is caused by high sodium levels in soils at concentrations greater than 15 % of the cation exchange capacity. Sodic soils tend to have poor structure with physical properties such as poor water infiltration and air exchange, which can reduce plant growth (Senon *et al.*, 2012). Warrence *et al.* (2003) outlined the principal effects of soil sodicity as reduced infiltration, reduced hydraulic conductivity, surface crusting and reduced crop yield. Increasing salt concentration may have a detrimental effect on soil microbes as a result of direct toxicity as well as through osmotic stress (Tate, 1995; Salehi *et al.*, 2008). Soil pH may be affected if significant fertilizer salts are present (Hardy, 2008). The presence of salt will lower soil pH reading compared to the absence of salts; the lower pH is often referred to as salt depression of pH. Salts may depress pH slightly (0.1 pH units) or by as much as 1.0 pH units (Hardy, 2008).

Irrigation water, groundwater and soils in the irrigable area of irrigation schemes should be monitored for salinity and waterlogging because these two negative environmental impacts as a result of irrigation have to be known to avoid the damage to sensitive crops and groundwater fluctuation can adversely affect crop production if the water table rises into the rootzone (Sener *et al.*, 2007). Salinisation monitoring should be done probably every year (Eswaran and Kapur, 1998). Several researches have been carried out in the irrigation schemes in Northern Ghana but there is no information on soil quality specifically salinity and sodicity levels in the irrigable areas. After several years of continuous cropping both dry and rainy seasons, it is imperative to monitor the quality of the soils in the irrigable areas of the irrigation schemes in Northern Ghana. This paper assessed soil pH, salinity and sodicity levels in the irrigable areas of six (6) irrigation schemes in Northern Ghana.

2. Materials and Methods

2.1 Description of Study Areas: The study was carried out in the Tono, Vea and Doba irrigation schemes in the Upper East Region and the Libga, Golinga and Bontanga irrigation schemes in the Northern Region of Ghana in 2015. The Tono and Doba irrigation schemes are located in the Kassena-Nankana Municipality and the Vea irrigation scheme is situated in the Bongo District of Upper East Region of Ghana. The Libga, Bontanga and Golinga irrigation schemes respectively are located in the Savelugu, Kumbungu and Tolon Districts of the Northern Region of Ghana. The crops grown in the schemes include rice (*Oryza sativa*), tomatoes (*Lyocopersicon esculentus)* and onion (*Allium cepa*), cowpea (*Vigna unguiculata*), okra (*Hibiscus esculentus)* and roselle (*Hibiscus sabdariffa)*. Other principal characteristics of the schemes are presented in Table 2.1.

Table 2.1: Principal Characteristics of the Irrigation Schemes

Irrigation Scheme	Tono	Vea	Doba	Libga	Bontanga	Golinga
Year Construction Started	1975	1965	1956	1969	1980	1971
Year Construction Completed	1985	1980	1956	1980	1986	1976
GPS Coordinates of the Irrigation Schemes	N 10° 84' W 1° 10'	N 10° 86' W 0° 84'	N 10° 86' W 1° 04'	N 9° 59' W 0° 85'	N 9° 57' W 1° 02'	N 9° 4' W 1° 0'
Potential Irrigable Area (ha)	3860	1,197	12	40	800	100
Developed Irrigable Area (ha)	2490	859	7	16	495	40
Management	ICOUR	ICOUR	WUA	GIDA	GIDA	GIDA
Mode of water Delivery	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity
Catchment Area (km^2)	650	136	0.65	165	165	124
Upland Soil Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Lowland Soil Texture	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Sandy loam

ICOUR – Irrigation Company of Upper Region, WUA- Water Users Association, GIDA – Ghana Irrigation Development Authority, GPS – Geographical Positioning System (Source: Project Records, 2015)

Northern Region is characterised by one rainy season (unimodal) and total annual rainfall of about 1,000 - 1,300 mm. The rainy season is about 140 - 190 days in duration. The rainy season is from May to October in a normal year, with peak rainfall occurring in August and September. The other months (November – May) are very dry, leaving domestic and agricultural sectors to struggle for the scanty water resources available in the basin (Kranjac-Berisavljevic, 1999). Temperatures in this region are consistently high with an annual average of 29 °C. The estimated reference evapotranspiration (ET_o) in the region is above 1,600 mm/yr (Kranjac-Berisavljevic, 1999; Abdul-Ganiyu, 2011). Relative humidity is generally low during the dry season, when average values are below 50 %; while temperatures and wind velocities are generally higher in the dry season. This necessitated the construction of irrigation schemes in the region to store runoff water in earth dams to ensure water availability for irrigation of cereals and vegetable crops for the long period of the dry season (Abdul-Ganiyu *et al*., 2015).

The Upper East Region is also characterized by mono-modal rainy season starting between April and May and lasting until the end of September or beginning of October. Rainfall is erratic and spatially variable. Average annual rainfall ranges between 700 - 1,010 mm per year with peak rainfall occurring in late August or early September. Annual evapotranspiration is generally twice the annual precipitation and therefore, water storage reservoirs provide an important source of water supply during the dry season (Mdemu *et al.*, 2008). Temperatures in the region are consistently high (23 - 39.1 °C). Relative humidity is high during rainy season and low during the dry season. The largest part of the region belongs to the Guinea Savannah Agro-Ecological Zone, that is, an ecological association in which tall grasses are dominant and sparse trees are also present. Also, small part of the region belongs to the Sudan Savannah Agro-Ecological Zone (Mdemu *et al.,* 2008).

2.2 Data Collection: The materials used for field data collection include; soil auger and soil sampling bags for soil samples storage in the irrigable areas and Global Positioning System (GPS) for taking coordinates of sampling. The irrigable areas of the schemes were divided into three blocks namely; upstream, midstream and downstream for the soil sampling. Composite soil samples (0 – 30 cm depth) were taken in each stream. Three (3) samples were taken in each irrigation scheme. A total of eighteen (18) soil samples were taken from the six (6) schemes at the locations presented in Table 2.2. The samples were analyzed in the Laboratory for pH, electrical conductivity (salinity), exchangeable sodium percentage (sodicity), sodium and cation exchange capacity.

Table 2.2: Soil Sampling Points in the Irrigable Areas of the Schemes

Scheme	Location	Latitude (°)	Longitude (°)	Altitude (m)
	US	N 10.86916	W 001.13835	176
Tono	MS	N 10.80809	W 001.12694	161
	DS	N 10.74831	W 001.12641	154
	US	N 10.86426	W 000.85694	185
Vea	MS	N 10.84960	W 000.84960	183

	DS	N 10.83937	W 000.87577	179
	US	N 10.86419	W 001.03518	172
Doba	MS	N 10.86157	W 001.03495	171
	DS	N10.85978	W 001.03577	171
	US	N 09.59627	W 000.85387	149
Libga	MS	N 09.59811	W 000.85392	147
	DS	N 09.60071	W 000.85520	144
	US	N 09.57848	W 001.02898	128
Bontanga	MS	N 09.59785	W 001.03280	125
	DS	N 09.61747	W 001.03376	120
	US	N 09.35713	W 000.95148	148
Golinga	MS	N 09.35306	W 000.95006	143
	DS	N 09.35079	W 000.94925	137

UP – Upstream, MS – Midstream and DW – Downstream

2.3 Laboratory Methods: Soil pH was determined using the glass electrode HT 9017 pH meter in a 1: 2.5 soil to distilled water (soil: water) ratio (IITA, 1979). Salinity was determined by measuring the electrical conductivity (EC) of a solution extracted from a soil wetted to a saturation paste **(**Senon *et al.*, 2012**)**. The Exchangeable Sodium Percentage (ESP) procedure was used to determine sodicity levels in the soils (Senon *et al.*, 2012). The Cation Exchange Capacity was determined using the ammonium acetate saturation method as described by Hesse (1970).

2.4 Data Analysis: GENSTAT was used for the analysis of variance (One-way ANOVA)**.** Tables and graphs were obtained using Microsoft Excel 2010 and these were used in presenting the results.

3. RESULTS AND DISCUSSIONS

3.1 pH of Soils in the Irrigable Areas of the Schemes

Figure 3.1 presents the pH of the soils in the irrigable areas of the schemes. The results presented in Figure 3.1 showed that the pH of the soils from all the schemes except Libga are fairly uniform, that is, slightly acidic with average values of 5.2 – 6.4 while the soils from the Libga scheme have a pH of 8.8 which is slightly alkaline. The analysis of variance (ANOVA) performed at 5 % level of significance on pH of soils for the various schemes gave F pr value of < 0.001, hence pH for soils among the irrigation schemes are statistically significant. With reference to LSD of 0.523, there is a significant difference between pH at Libga and all the other schemes. The alkalinity nature of the Libga scheme soils can be attributed to the high levels of sodium (440.7 mg/kg) in the soils. The slightly acidic nature of soils from Tono, Vea, Doba, Bontanga and Golinga might also be attributed to the lower levels of sodium ranging from 47.3 - 81.3 mg/kg in the soils. According to Senayah *et al.* (2009), soil pH within the drier Savannah agro-ecological zones, particularly both the Volta and Lima series are strongly acid (mostly less than 5.0). The top soil pH ranges from strongly acid to neutral for Lapliki series. Buri *et al.* (2006) stated that exchangeable acidity is also relatively higher within the savannah agro-ecology which can adversely affect basic cation balances particularly Ca and Mg leading to adverse effect on crop growth especially rice.

A pH range from 5.5 - 7.0 is suitable for most vegetable crops (Liu and Hanlon, 2012). This pH range can assure high bioavailability of most nutrients essential for vegetable growth and development (Ronen, 2007). At soil pH 8.0 or higher, iron and/or manganese bioavailability cannot satisfy most vegetable crops' requirements. However, when soil pH reaches 5.0 or lower, aluminum, iron, manganese, and/or zinc solubility in soil solution becomes toxic to most vegetable crops (Osakia *et al.*, 1997). The bioavailability of most nutrients is controlled by soil pH, thus, as soil pH increases, the bioavailability decreases for P, Fe, Mn, B, Zn, and Cu. As soil pH decreases, the bioavailability decreases for Ca, Mg and Mo (Liu and Hanlon, 2012). According to Whiting *et al.* (2014), pH 6.0 – 7.5 is acceptable for most plants growth and development, pH 4.6 is too acidic for most plants, pH 5.5 reduces soil microbial activity and pH > 8.3 is too alkaline for most plants. This means that the soils at Tono (pH 6.1) and Vea (pH 6.4) are within the acceptable limits for optimum plant growth and development whereas the soils at Doba (pH 5.4), Bontanga (pH 5.5) and Golinga (5.2) can potentially reduce microbial activity. The Libga soils (pH 8.8) are too alkaline for plant growth and development resulting in poor yield.

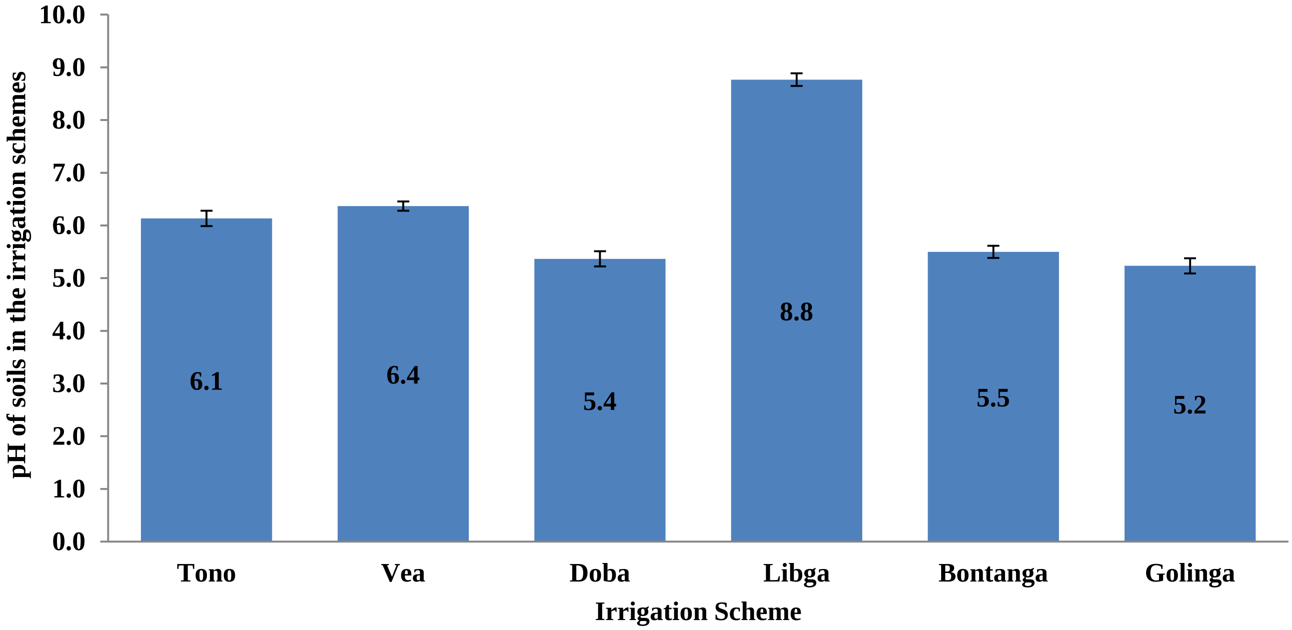

Figure 3.1: Soil pH in the Irrigable Areas of the Schemes

3.2 Soil Salinity of the Irrigable Areas

Electrical conductivity (EC) which describes the levels of salinity in soils was measured in all the soil samples collected from the irrigation schemes and presented in Figure 3.2. The average concentrations (Figure 3.2) of EC of the various schemes namely; Tono, Vea, Doba, Bontanga, Golinga, and Libga were (11.7 µS/cm), (17.7 µS/cm), (1.2 µS/cm), (20.7 µS/cm), (39.3 µS/cm), and (1,143.4 µS/cm) respectively. The mean values recorded except Libga are within the recommended range for crop production. The Libga scheme recorded significantly high salinity levels of 317 – 4,106 µS/cm with a high mean level of 1,143.3 µS/cm. This may be attributed to higher concentrations of cations such as sodium and potassium (Khai *et al*., 2008). Analysis of variance performed at 5 % level of significance yielded F pr value of < 0.001, thus electrical conductivity among the soil samples of the schemes are statistically significant. Low salinity level suggests that injury to plants is very little whiles high salinity level indicates that most high salt tolerant plants such as grain sorghum and maize will show injury and low/moderate salt-sensitive plants such as rice, onion, tomato, pepper, cabbage and okra will show severe injury including stunting, chlorosis and severe dwarfism (Igartua *et al*., 1994; Krishnamurthy *et al*., 2007). As a result of high salinity levels in the soils of the Libga scheme, moderate salt tolerant crops like tomato, cabbage, lettuce, carrot and onion are not cultivated on the scheme except roselle, jute mallow, okra, pepper and rice. The 4,106 µS/cm EC recorded at the Libga downstream is described as high which indicates that, the growth and yield of most low and moderate salt-sensitive crops like tomato, okra and other salt sensitive vegetables can be severely affected.

Plate 3.1 illustrates patches of land affected with salinity in Libga irrigation scheme. One of the causes of the salinity in the scheme over the time is the accumulation of salts as a result of the continuous application of inorganic fertilizers such as urea, compound fertilizers (NPK) and ammonia for about 46 years without proper drainage network which causes waterlogging and high water tables. Similar management practices may be observed at the other schemes but with a minimal residual effect probably due to proper management. The total area affected by salinity is estimated to be about 2 ha in various patches. Horneck *et al.* (2007) stated that salinity in soil can originate from soil parent material; from irrigation water, from fertilizers or other soil amendments. Ijir (1994) indicated that the high soil salinity levels in the Wurno scheme were caused by waterlogging due to poor water control and drainage system. Horneck *et al.* (2007) and Senon *et al.* (2012) reported that salinity in irrigated soils can reduce crop yields, reduce the effectiveness of irrigation, reduces water availability for plant use, ruin soil structure and affect other soil properties. Warrence *et al.*

(2003) outlined the principal effects of soil sodicity as reduced infiltration, reduced hydraulic conductivity, surface crusting and reduced crop yield.

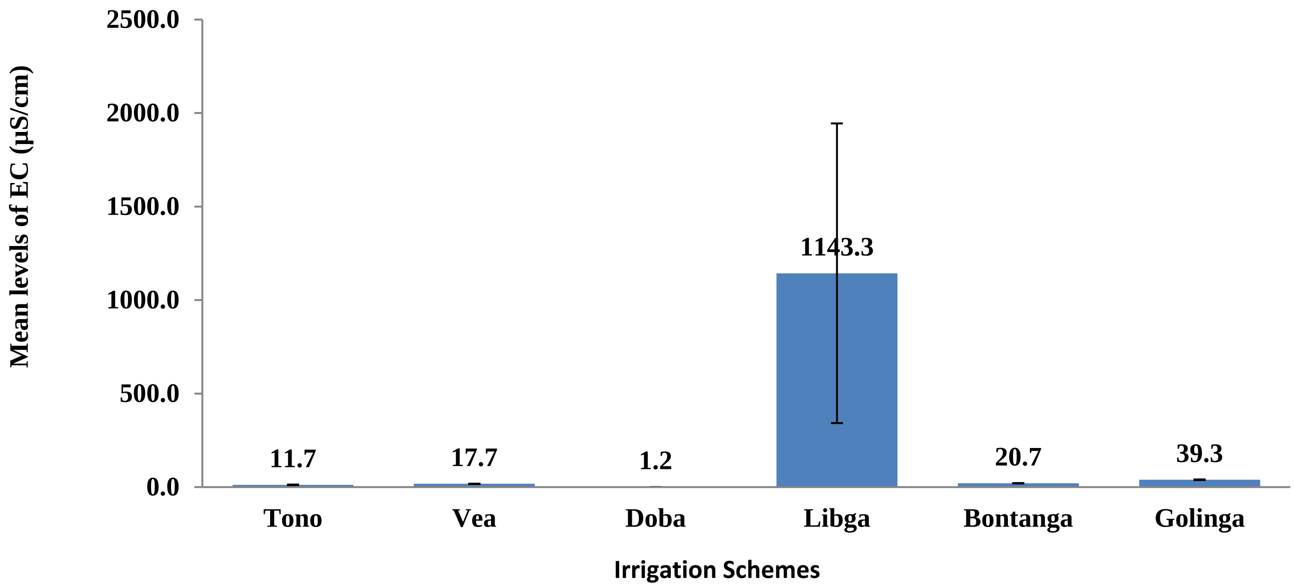

Figure 3.2: Soil Salinity of the Irrigation Schemes

Plate 3.1: Effects of Salinity on Crop Fields at Libga Irrigation Scheme

3.3 Soil Sodicity of the Irrigable Areas of the Schemes

The sodicity levels in the soils were determined using the Exchangeable Sodium Percentage (ESP) indicator and the results are presented in Figure 3.3.

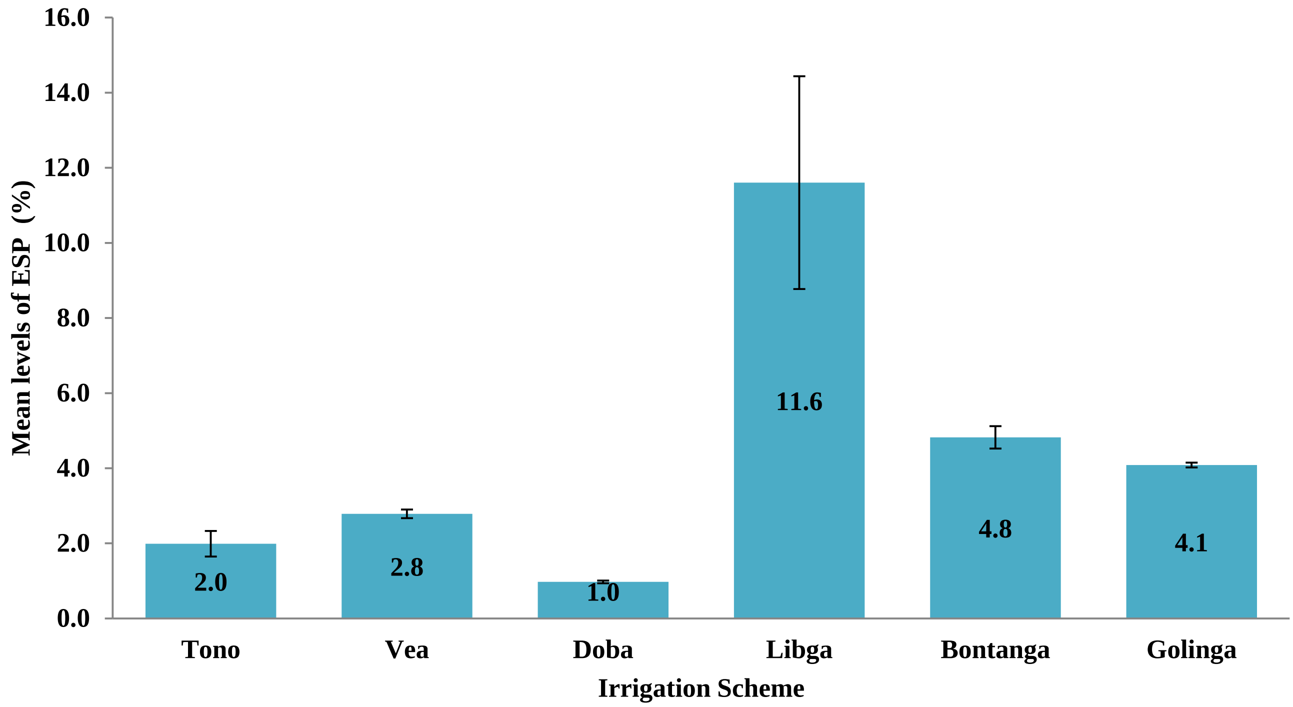

Figure 3.3: Soil Sodicity of the Irrigable Areas

The results showed that sodicity levels are low at Tono (2.0 %), Vea (2.8 %), Doba (1.0 %), Bontanga (4.8 %) and Golinga (4.1 %). Low levels of ESP necessitate low EC (Hanson and Graaff, 1990). ESP and EC concentrations in all the schemes except Libga are low; hence the soils are presently free of salt-related problems (salinity and sodicity). However, the Libga scheme recorded moderately high to excessively high sodicity levels of 8.5 – 30 % with an average level of 11.6 %. The upstream recorded the lowest sodicity level of 8.5 % whereas the downstream recorded the highest sodicity level of 30 %. Analysis of variance performed at 5 % level of significance gave F pr = 0.018, indicating that there was significant difference in the sodicity levels of the various irrigation schemes.

The Natural Resources Conservation Service (2003) reported that, soils with ESP less than 15 % are normal soils whereas soils with ESP greater than 15 % are sodic soils and soils with electrical conductivity (EC) above 4,000 µS/cm and exchangeable sodium percentage (ESP) above 15 % are described as saline-sodic soils (Horneck *et al.*, 2007). By way of comparing the schemes, it can be observed that, Tono, Vea, Doba, Bontanga, Golinga and Libga (upstream/midstream) irrigable soils are normal but sodic at Libga (downstream). Therefore, the Libga downstream soil can be best described as saline-sodic since the soil have EC of 4,106 µS/cm and ESP of 30 %. Senon *et al.* (2012) reported that sodic soils tend to have poor structure with physical properties such as poor water infiltration and air exchange, which can reduce plant growth. Warrence *et al.* (2003) outlined the principal effects of soil sodicity as reduced infiltration, reduced hydraulic conductivity, surface crusting and reduced crop yield.

3.4 Sodium (Na) Level in Soils of the Irrigable Areas of the Schemes

The results of the levels of sodium (Na) in the soils of the irrigable areas of the schemes are presented in Figure 3.4

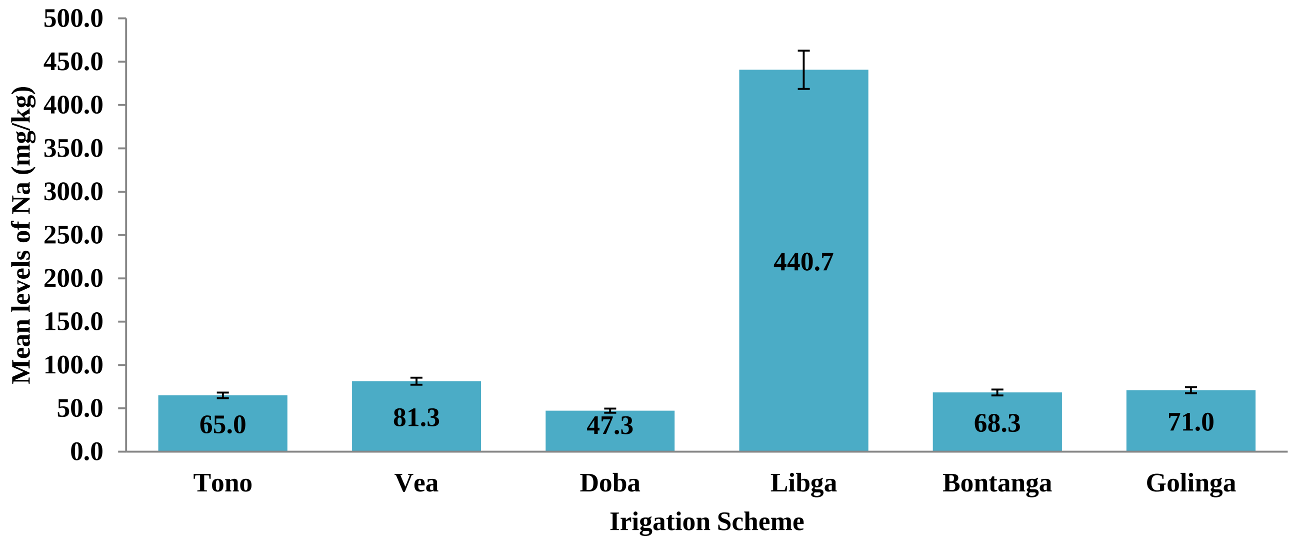

Figure 3.4: Mean Levels of Sodium in the Irrigable Areas of the Irrigation Schemes

Sodium is a micronutrient that aids in metabolism, specifically in regeneration of phosphoenolpyruvate, involved in the biosynthesis of various aromatic compounds, and in carbon fixation (Pohl *et al*., 2013). The sodium levels in the soils in the irrigable areas of the various schemes were found as Tono (65.0 mg/kg), Vea (81.3 mg/kg), Doba (47.3 mg/kg), Libga (440.7 mg/kg), Bontanga (68.3 mg/kg) and Golinga (71.0 mg/kg). This indicates that all the schemes have low sodium levels except Libga (440.7 mg/kg) which has high levels and these levels are hazardous to the crops grown. According to Salinity Management Guide (2007), most plants especially vegetables will typically suffer injury if sodium in soil exceeds 230 mg/kg. The excess sodium (440.7 mg/kg) in the Libga scheme's soil contributes directly to the total sodicity of the soil which is toxic to sensitive crops like okra, tomato, onion and pepper which are commonly grown in the schemes. Zhu (2001) reported that excess sodium in soil limits the uptake of water due to decreased water potential, which may result in wilting. It may also be stored in old plant tissue, limiting the damage to new growth. The study revealed that all the schemes except Libga scheme are free from problems associated with excess sodium in irrigable areas. Sodium ions cause deflocculation of particles and subsequent sealing of soil pores thereby preventing water passage into the soil (Warrence *et al.,* 2003). An excess of sodium can decrease the soil's permeability and the soil's tilth (Salinity Management Guide, 2007). Build-up of sodium in plants causes toxic levels, which cause stunted growth and arrested cell development (Salinity Management Guide, 2007).

3.5 Cation Exchange Capacity (CEC) in the Soils of the Irrigable Areas

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, sodicity, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants (Hazleton and Murphy, 2007). Figure 3.5 presents the CEC in the soils of the irrigable areas. Figure 3.5 shows the mean concentration of CEC levels in the irrigable areas of the schemes: Tono (16.7 cmol/kg), Vea (13.0 cmol/kg), Doba (19.5 cmol/kg), Libga (7.9 cmol/kg), Bontanga (15.6 cmol/kg), and Golinga (10.7 cmol/kg). Analysis of variance performed at 5 % level of significance yielded an F pr value of 0.001. This indicates that there is a significant difference among the soils of the schemes. With reference to LSD of 1.34, no significant difference exists among the mean concentration levels of the soil at Tono and Bontanga. Brady *et al.* (2008) stated that CEC of soils < 10 is considered as low, CEC ranging from 10 - 20 is moderate and CEC > 20 is high. It indicates that CEC in Tono, Vea, Doba, Bontanga and Golinga are moderate whiles CEC in Libga is low. CEC is linked closely to the organic matter content of the soil. The lower CEC at Libga may be attributed to the lower organic matter content of the soil, high salinity and sodicity levels (Alhassan, 1996).

Low CEC has the potential of reducing the water holding capacity of the soil which in effect can cause a reduction in plant productivity (Bauer and Black, 1994). Soils with a low CEC are more likely to develop deficiencies in potassium (K^+), magnesium ($Mg^{2}+$) and other cations while high CEC soils are less susceptible to leaching of these cations (CUCE, 2007). High CEC soils generally have greater water holding capacity than low CEC soils (Brown and Lemon, 2015).

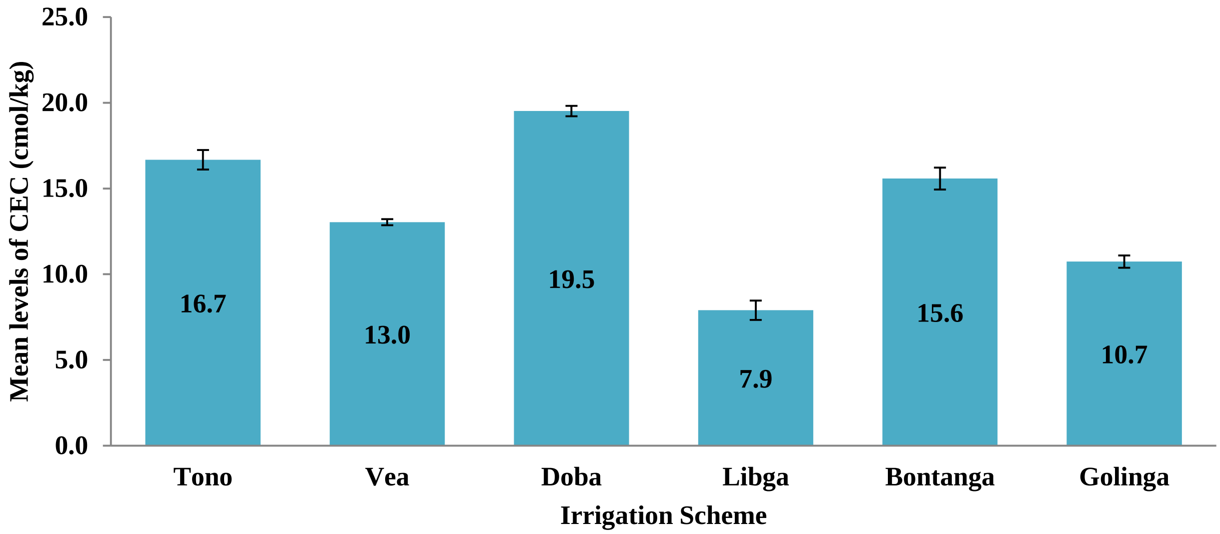

Figure 3.5: CEC in the Soils of the Irrigable Areas of the Irrigation Schemes

3.6 Stability of the Developed Irrigable Areas of the Schemes

The environmental stability index was used to evaluate the stability of the developed irrigable areas of the schemes regarding salinity, sodicity, waterlogging and erosion as a result of adverse impact of irrigation (Ijir, 1994). The results are presented in Table 3.1

Table 3.1: Environmental Stability Index of the Irrigable Areas

Scheme	Developed Area (ha)*	Total Developed Area Affected (ha)*	Type of Environmental Problem in the Scheme*	Total Developed Area Unaffected (ha)*	Environmental Stability Index (%) **
Tono	2,490	59	waterlogging, erosion	2,431	98
Vea	850	44	waterlogging, erosion	806	95
Doba	7	0	-	7	100
Libga	16	2	waterlogging, salinity, sodicity	14	86
Bontanga	495	0	-	495	100
Golinga	40	0	-	40	100

(Source: * – Project Records, 2015 and ** – Desk Computation, 2015)

The Doba, Bontanga and Golinga irrigation schemes are environmentally stable as each recorded an environmental stability index of 100 %. The irrigable areas of the schemes are presently free of erosion, waterlogging, salinity and sodicity problems.

Waterlogging and erosion were recorded in the Tono and Vea irrigation schemes but the situation is not yet acute as they recorded an environmental stability index of 98 % and 95 % respectively. At Tono, the waterlogging is caused by the seepage from the broken laterals. Some portions of the uplands of the irrigable areas are eroded annually during heavy rains.

At Vea, the causes of the waterlogging include:

- Poor drainage network,
- Improper water control,
- Leakages or seepage from canals and laterals and,
- Spillage from canals due to poor water control by water bailiff.

As a result of the poor state of the canals and laterals, most farmers resort to lifting water from the main drain using pumps for irrigation, thus making the water bailiff deliberately opening the water to spill-over the canal banks (Plate 3.2) and subsequently flow to the main drain for such farmers to use. This practice consequently causes waterlogging in some fields which may subsequently cause salinity in the irrigable area.

Plate 3.2: Spillage from Canal Causing Waterlogging in the Vea Irrigation Scheme

Libga Irrigation Scheme: Following the continuous cultivation in the scheme for 46 years, the irrigable area of the scheme is becoming unstable as it recorded an environmental stability index of 86 %. The problem of salinity was identified since 2009 and it is said to be increasing especially the downstream portions of the irrigable area. The total area affected by salinity is estimated to be about 2 ha in various patches. According to Ijir (1994), the notional normal environmental stability index of irrigable area is in a range of 90 – 100 %, but the author found the environmental stability index of the Wurno Irrigation Scheme in Nigeria to be 87.5 %. This means that the 86 % index for the Libga irrigation scheme slightly fell below the normal index due to the prevalence of salinity, sodicity and waterlogging. Sener *et al.* (2007) reported 99 % environmental stability of the irrigable area for the Hayrabolu Irrigation Scheme in Turkey.

Plate 3.3: Waterlogged Fields at the Libga Irrigation Scheme

4. CONCLUSSIONS

The results of the study revealed that the soils at Tono (pH 6.1) and Vea (pH 6.4) are within the acceptable limits for optimum crop growth and development whereas the soils at Doba (pH 5.4), Bontanga (pH 5.5) and Golinga (5.2) are also good for crop growth but can potentially reduce microbial activity. The Libga soils with pH 8.8 are too alkaline for crops growth and development resulting in poor yield. The irrigable area in the Libga scheme is affected with relatively high levels of salinity and sodicity problems, thus adversely affecting crop production in the scheme. The Tono, Vea, Doba, Bontanga and Golinga schemes have no salinity or sodicity problems. The sodium levels in the soils of Tono, Vea, Doba, Bontanga and Golinga are within the acceptable limits for crop production whereas the sodium level in the soils of Libga scheme exceeded the acceptable limits. The cation exchange capacity (CEC) in the soils at Tono, Vea, Doba, Bontanga and Golinga schemes are moderate whiles the CEC in Libga is low. The irrigable areas of Doba, Bontanga and Golinga schemes are environmentally stable whereas that of the Libga scheme is environmentally stable due to salinity, sodicity and waterlogging. It is recommended that the management of the schemes should ensure proper water delivery and management in the schemes to avoid waterlogging and deep percolation which could subsequently cause salinity. Cracks and breaches on canals and laterals should be repaired as and when they occur to avoid seepage. The drainage networks in the schemes should be cleaned periodically and regularly to ensure proper drainage. Excessive application of inorganic fertilizers should be avoided by farmers. The management of the schemes especially the Libga scheme should periodically and regularly monitor pH, salinity and sodicity levels in the irrigable areas.

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