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Assessment of Irrigation Water Salinity and Crop Production at Botanga Irrigation Scheme

Adams Sadick[1*], Richard Amfo-Otu[2], Emmanuel Dugan[3], Calys-Tagoe Edward[4]

[1]Analytical Services, Soil Research Institute, Kumasi, Ghana

[2]Environmental and Natural Resources Management, Presbyterian University College, Akuapem Campus, Ghana.

[3]Soil and Water Conservation, Soil Research Institute, Kumasi, Ghana

[4]Department of Soil Fertility, Soil Research Institute, Kumasi, Ghana.

*Corresponding author：Adams Sadick

Analytical Services, CSIR-Soil Research Institute, Kumasi, Ghana

Cell phone: +233268198126

Abstract

A research was conducted at Botanga irrigation area to assess the levels of selected irrigation water quality parameters. The parameters considered were pH, electrical conductivity (EC_w), total dissolved solids (TDS), calcium (Ca), magnesium (Mg), sodium (Na), sodium adsorption ratio (SAR) and bicarbonate (HCO_3^-). Water samples were collected from the dam, main canal and laterals for analysis. The results showed that all the selected irrigation water quality parameters were found with the maximum allowable limit, and the value of HCO_3^- was low to precipitate $CaCO_3$ in the water thereby increasing the value of Na and SAR. The water was therefore suitable for irrigation.

Keywords: Irrigation, water quality, Botanga, salinity, crop production

Introduction

Nearly all waters contain dissolved salts and trace elements, many of which result from the natural weathering of the earth's surface. In addition, drainage waters from irrigated lands and effluent from city sewage and industrial waste water can impact water quality. In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. However, a number of trace elements are found in water which can limit its use for irrigation (Alagbe, 2006).

Irrigation water quality can have a profound impact on crop production. All irrigation water contains dissolved mineral salts, but the concentration and composition of the dissolved salts vary depending on the source of the irrigation water. Too much salt can reduce crop production while too little salt can reduce water infiltration, which indirectly affects the crop (Ayres and Westcot, 1985).

Crop production in the arid and semi-arid regions is dependent on irrigated agriculture. The hot and dry climates of these regions require that the irrigation water does not contain soluble salts in amounts that are harmful to the plants or have an adverse effect on the soil properties. Water of such quality is usually not available in sufficient quantities to satisfy the water requirements of all the crops grown. Under these conditions the farmers are obliged to use irrigation water with high quantities of dissolved salts, invariably accompanied by yield reductions of most crops. Indiscriminate use of such water can often lead to crop failures and to the development of saline or sodic soils which, in turn, require expensive treatment to make them productive again. On the other hand, when saline water is skillfully used, it can contribute to the successful production of a variety of crops (Abdul-Ganiyu et al., 2012).

Botanga irrigation is the second renowned irrigation scheme in the northern part of the country apart from Tono irrigation location in the Upper East Region of Ghana. An extensive research has been conducted at Tono irrigation scheme by the author of this paper but unfortunately, not many studies especially on water quality have been done at Botanga irrigation water. It is therefore imperative to look at the water quality aspect of the Botanga irrigation water based on the current situation (Richards, 1954).

1. Materials and methods

Botanga irrigation scheme is located in the northern region of Ghana, in the Tolon Kumbungu district; it lies between latitude 9° 30” and 9° 35” N and longitude 1° 20” and 1° 04” W. Figure 1 shows the study area.

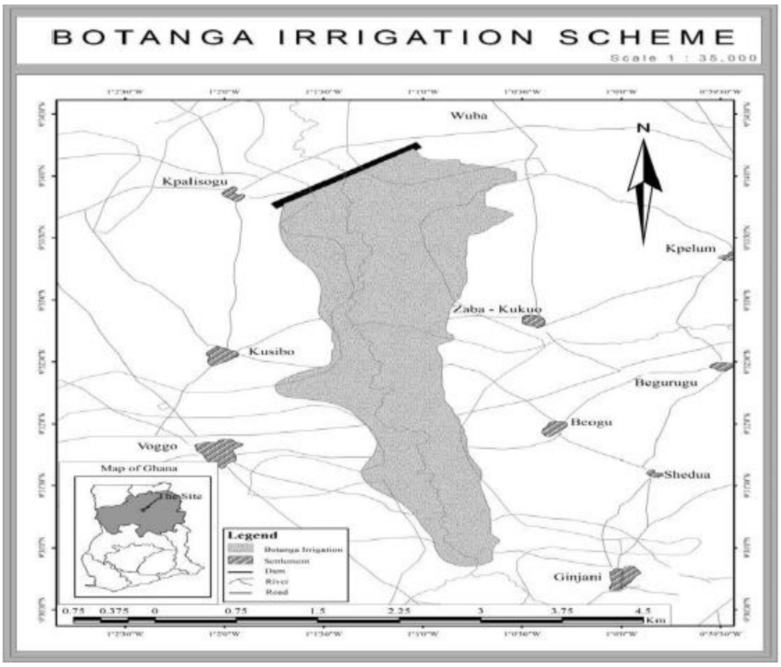

Figure 1. Location of Botanga irrigation scheme (Adams et al., 2014)

The cropping area is divided into two, upland and lowland, the upland is free draining soil and plots are designed for furrow irrigation. The upland area is for vegetables production and the lowland for rice production because of the nature of the soil that is heavily textured and irrigated by flooding (Abdul-Ganiyu et al., 2012).

The irrigation system is an earth fill dam of 12 m in height with a crest level of 5.00 m. The spillway level is at an elevation of 5.8 m and the surface area at the spillway elevation is 770 m2. The reservoir capacity is 25 million m^3. The dead storage elevation is about 1.52 m and the dead storage capacity is 5 million m^3. The spillway type is drop inlet with a length of 83.7 m and a design discharge of $85m^3$/sec. An emergency spillway is also provided. The irrigation system has potential area of 570 ha and all the areas have been developed (Abdul-Ganiyu et al., 2012).

The system works under gravity from the dam through the canals, laterals to various farms. The maximum, minimum and dead storages of the reservoir are 25 million m3, 20 million m3 and 5 million m3 respectively, two (2) canals and twenty eight (28) laterals aid in the distribution of water to the farms. Thirteen (13) villages benefit from the dam, which includes Tibung, Kumbungu, Kpasogu, Dalun, Wuba, Kukuo, Kpong, Saakuba, Yiplegu, Voggu, Kushibo, Zangbalwe and Bagli (Abdul-Ganiyu et al., 2012).

2. Water Sampling and Analysis

A total of eighteen (18) water samples were collected from the dam, main canal, and some randomly selected laterals of all the command areas. This was done during cropping period of the peak dry season which was the time of major irrigation (Adams et al., 2014). Each sample was a composite of 3 sub-samples. The bottles used for sampling were cleaned with hydrochloric acid (HCl) and rinsed repeatedly with deionized water as suggested by De, 1989. The bottles were kept air tight and labelled properly for identification. Stoppering of the bottles was done quickly to avoid aeration during sampling.

Electrical conductivity (EC), pH and temperature of the samples were measured on the spot using portable EC-meter, pH-meter and thermometer, respectively. Total dissolved solids (TDS) were estimated by the method described by Todd, 1980.

The samples collected from the study area were carefully transported to CSIR-Soil Research Institute's laboratory, Ghana and kept in a refrigerator for analysis. Na^{+} and K^{+} were determined by flame photometry (Jackson, 1967). Ca^{2+} and Mg^{2+} by Atomic Absorption Spectrophotometer (AAS) (Jackson, 1967: Page et al., 1982), HCO_3^{-} and CO_3^{2-} titration method (Jackson, 1967) and the Sodium Adsorption Ratio (SAR) by the method described by Richards, 1954.

3. Results & Discussion

Table 1 shows physico-chemical results of the analysis of water samples from Botanga irrigation water.

The pH of the study area was generally basic ranging from 7.40 to 7.57 with an average of 7.46. This average was identified to be within the acceptable range of irrigation water quality (WHO, 2004).

Primary effect of high EC_w water on crop productivity is the inability of the plant to compete with the ions in the soil solution of water. The higher the EC_w, the less water is available to the plants, even though the soil may appear wet, leading to low productivity (Adams et al., 2014). EC_w values from table 1 varied from 125.30 to 130.56 µscm^{-1} with average value of 126.84. This is within irrigation water quality standard set by World Health Organization and Department of Environment in Bangladesh.

EC_w and Na^+ play a very important role in suitability of water for irrigation (Page et al., 1982). Soil containing large contents of Na^+ with HCO_3^- or Cl^-/SO_4^{2-} turns a soil alkaline or saline respectively (Rao, 2005). Higher Na^+ content in irrigation water causes an increase in soil solution osmotic pressure (Rahman et al., 2012). Since plant roots extract water through osmosis, the water uptake of plants decreases. The osmotic pressure is proportional to the salt content or salinity hazard (Page et al., 1982). The salt, besides affecting the growth of plants directly, also affects the soil structure, permeability and aeration, which indirectly affect plant growth. Furthermore, high Na^+ and elevated carbonate content also cause displacement of exchangeable Ca^{2+} and Mg^{2+} from the clay mineral of the soil (Rahman et al., 2012). Thus, an increase of soil pH, nutrient availability and hindered microorganism activity in the soil.

$$Na - Clay + H_2O \rightarrow H - Clay + Na^+ + OH^-$$

$$CO_3^{\;2-} + H_2O \rightarrow HCO_3^{\;-} + OH^-$$

Another significant chemical parameter identified for assessing the degree of suitability of water for irrigation was sodium content or alkali hazard, which is expressed as the sodium adsorption ratio (SAR). SAR measures the potential dangers posed by excessive sodium in irrigation water (Alagbe, 2006). The average value of SAR was 0.07 which did not pose problem for the irrigation water according to University of California Committee of Consultants (UCCC, 1974). A high SAR value implies a hazard of sodium (alkali) replacing Ca^{2+} and Mg^{2+} in the soil through a cation exchange process that damages soil structure, mainly permeability, and which ultimately affects the fertility status of the soil and reduces crop yield (Gupta, 2005).

The average value of HCO_3^- in the study area was 1.29mg/l ranging from 1.25 to 1.34mg/l. Irrigation water rich in HCO_3^- content tend to precipitate insoluble Ca^{2+} and Mg^{2+} in the soil which ultimately leaves higher proportion of Na^+ and increases the SAR value (Michael, 1992) as:

$$2HCO_3^{\;-} + Ca^{2+} \rightarrow CaCO_3 + H_2O + CO_2 \uparrow$$

At the same level of salinity and SAR, adsorption of Na^+ by soils and clay minerals was greater at higher Mg: Ca ratios. This was because the bonding energy of Mg^{2+} was less than that of Ca^{2+}, allowing more Na^+ adsorption. This happened when the ratio exceeded 4.0 (Alagbe, 2006). In the study area, the ratio of Mg^{2+} and Ca^{2+} for all parameters was less than 1.0 (Table 4). Thus, it indicated a good proportion of Ca^{2+} and Mg^{2+}, which maintains a good structure and tilth condition. The presence of excessive Na^+ in irrigation water promotes soil dispersion and structure breakdown when Na^+ to Ca^{2+} ratio exceeds 3:1. Such a high Na:Ca ratio (>3:1) results in severe water infiltration problems, mainly due to lack of sufficient Ca^{2+} to oppose the dispersing effect of Na^+. Excessive Na^+ also creates problems in crop water uptake, poor seedling emergence, lack of aeration, plant and root diseases etc. Botanga irrigation water has not encountered such problem. Generally these parameters were within the acceptable range but higher than the results of the study done by Adams et al., 2014 at Tono irrigation area in the Upper East Region of Ghana. The values of the parameters also reduced as the water ran through the main canals to the laterals (Table 1). This might due to infiltration of the parameters in the soil as the water ran through the main canals to laterals.

Table 1: Physical parameters and cations levels of water samples

Location	pH	EC_w	TDS_w	Ca	Mg	Na	Ca:Mg	SAR	HCO_3^-	CO_3^{2-}
		μscm^{-1}	mg/l						mg/l	
Dam	7.57	130.56	81.24	0.65	0.43	0.35	1.51	0.07	1.34	1.10
Main canal	7.50	127.23	81.35	0.64	0.43	0.35	1.49	0.07	1.28	0.90
Lateral 1	7.43	125.65	77.98	0.64	0.43	0.31	1.49	0.07	1.28	0.90
Lateral 2	7.40	125.30	77.24	0.64	0.43	0.31	1.49	0.07	1.28	0.90
Lateral 3	7.40	125.48	77.25	0.64	0.43	0.31	1.49	0.07	1.25	0.90
Mean	7.46	126.84	79.01	0.64	0.43	0.33	1.49	0.07	1.29	0.94

4. Conclusions

Botanga irrigation scheme benefit from rainfall during rainy season but requires significant amount of water during dry season. The results concluded that the values of SAR, Na, Ca and Mg were within the acceptable range which made the water suitable for irrigation. Also the value of HCO_3^- was low to precipitate in the water to raise the values of SAR and Na in the water.

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