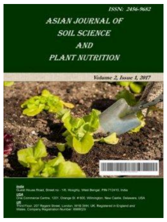

Asian Journal of Soil Science and Plant Nutrition

3(1): 1-7, 2018; Article no.AJSSPN.40577
ISSN: 2456-9682

Irrigation Suitability of Cheffa Valley Water Resources at Oromiya Special Zone in Ethiopia

Ali Seid[1*], Muktar Mohammed[2] and Seid Mohammed[3]

[1]Department of Plant Science, Wollo University, P.O.Box 1145, Dessie, Ethiopia.
[2]Department of Soil Science, Haramaya University, P.O.Box 138, Dire Dawa, Ethiopia.
[3]Department of Dryland Crop Science, Jigjiga University, P.O.Box 1020, Jigjiga, Ethiopia.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2018/40577
Editor(s):
(1) Paola Angelini, Professor, Department of Chemistry, Biology and Biotechnology, University of Perugia, Perugia, Italy.
Reviewers:
(1) Sunday Olufemi Adesogan, University of Ibadan, Nigeria.
(2) Renan Pan, State University of Western Parana, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/24123

Original Research Article

Received 13th January 2018
Accepted 26th March 2018
Published 13th April 2018

ABSTRACT

To achieve sustainable irrigated agriculture in potential areas of the country better understanding of the extent, type and distribution of soluble salts are decisive for effective control of soil salinity and sodicity problems. In line with this, this study was conducted in Kemissie district, Oromiya Zone of Amhara Regional State in Cheffa Valley of North Ethiopia. This study focused on irrigation water characterisation and classification at Cheffa Valley concerning salinity and sodicity. Underground water samples from five profiles excavated on representative locations in different land use and two irrigation water samples from Borkena River were collected and analysed. The underground water samples were moderately alkaline in reaction and highly saline in salt content while the Borkena River water samples were mildly alkaline in reaction and moderate in salt content. The Cl^- and HCO_3^- salts of Na^+ and Ca^{2+} ions are mainly contributing salinity and sodicity hazard in both underground and River water samples.Underground waters were high in soluble salt content, medium in sodicity and safe in residual sodium carbonate hazard while Borkena river is medium insoluble salt content, low in sodicity and safe in residual sodium carbonate hazard. Accordingly, the current result revealed that Borkena River is potentially suitable for irrigation

**Corresponding author: Email: aliseidmohammed@gmail.com;*

purpose while utilisation of underground waters for irrigation without treatment is aggravated salinity problem. Therefore, unless proper management practices were applied Soils of the area were prone to secondary salinisation.

Keywords: Ground water; Borkena River; characterisation; classification; salinity; alkalinity.

1. INTRODUCTION

The government of Ethiopia has adopted an Agricultural Development Led Industrialization strategy. To realise this, the government has adopted a long-term strategy to achieve faster growth and economic development by making use of technologies that are labour using but land augmenting [1]. From all natural resources land and water, resources are the primary elements required for rapid agricultural development to assure food self-sufficiency and to increase per capita income of the farming community. In the direction of this, to date considerable effort has been made in this direction to use available water and land resources in potential areas of the country through intensification using irrigation and other technologies to increase agricultural production and productivity.

Consequently, the agricultural GDP has shown an increasing trend in recent years. For instance, it grew by 19% in 2003/2004 and production of food grains increased by 39% over the 2002/2003 [2]. However, such intensification of agriculture through development of irrigation on potential areas of the country creates negative impacts on our soil resource through development of soil salinity, sodicity and /or alkalinity problems which are the major types of land degradation on irrigated areas of the world in general and that of the country in particular. Considerable area of land is becoming unproductive every year because of salinity and sodicity. Due to the dependence on rainfed agriculture on soil acidity in the highlands and the problem of soil salinity and /or sodicity in the lowland remains the major challenge in Ethiopia. Due to this, thus a significant population depend on food aid handouts.

The development of salt-affected soils and associated problems are most pronounced in arid and semi-arid regions of the earth, which offer considerable promise for development as major food-producing regions, because of their frequent potential for multiple cropping. Salinization of soil is one of the major factors limiting crop production particularly in arid and semi-arid regions of the world [3]. Irrigation, evaporation, shallow water table depth and the insufficient annual rainfall to leach down salts from the plant rooting zone favour excessive accumulation of soluble salts in soils of arid and semi-arid regions [4,5,6].

In some areas known to be good agricultural lands years back, farmers have even abandoned their land because of low crop productivity and total crop failure due to negative effects of excess salt concentrations within their farmland. High economic development to achieve millennium development goal (MDG) through insuring food security within the country should be warranted by appropriate assessment and characterization of the extent and magnitude of soil salinity and sodicity in the irrigated and potentially irrigable areas of the country. Hence, this study will provide information on salinity and sodicity status of water resources in the Borkena River basin that is among the potential irrigation areas in the Oromiya Special Zone in the Amhara Regional Sate of Ethiopia. Therefore, this study was initiated to assess and evaluate the chemical properties and quality of the irrigation waters sources of Cheffa Valley and classify them to the standard suitability classes of irrigation waters.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in at Cheffa Valley, which is located in the Oromiya Administrative Zone of Amhara National Regional State (Fig. 1). Specifically, it is located 350 km north from Addis Ababa with specific geographical location of 10° 55' 09.5" N latitude and 39° 48' 27.8" E longitude bounded by South Wollo Zone on the north, North Shewa Zone on the southwest and Hari-Resu Zone of Afar Regional State in the east direction. The study site has low-lying bowl-shaped landform topography where the middle plain is agricultural land grazing land dissected by Borkena River with an altitude range from 1000-1450 meters above sea level.

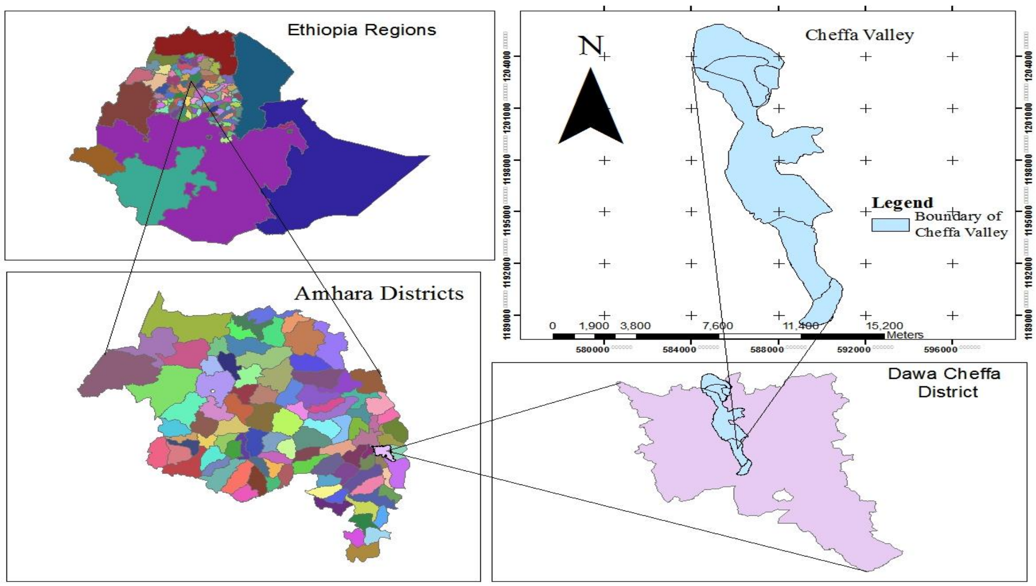

Fig. 1. Location map of the study area

Based on rainfall and temperature data from January 1990 to July 2013 obtained from Kobolcha Meteorological Station, the area is characterised by bi-modal rainfall pattern with mean annual rainfall 900.6 mm and mean annual minimum and maximum temperature of 14.1 and maximum 30.7°C respectively (Fig. 2). Short rainy season starts from March to May and main rainy season starts from early July extended to the late September.

2.2 Irrigation Water Sampling

Water samples for this study were collected from the Borkena River that is the main water source for irrigation and underground water samples were collected from the profile excavation sites. A total of seven samples of irrigation waters two from Borkena River at different locations and five underground water samples from respective profile excavation sites were collected. The collection and handling of the irrigation water samples were done in accordance with the procedures outlined by the US Salinity Laboratory Staff [4].

2.3 Analysis of Irrigation Waters

Water sample collected from the Borkena River and underground water samples, which were collected during profile excavation were analysed for their respective chemical parameters related

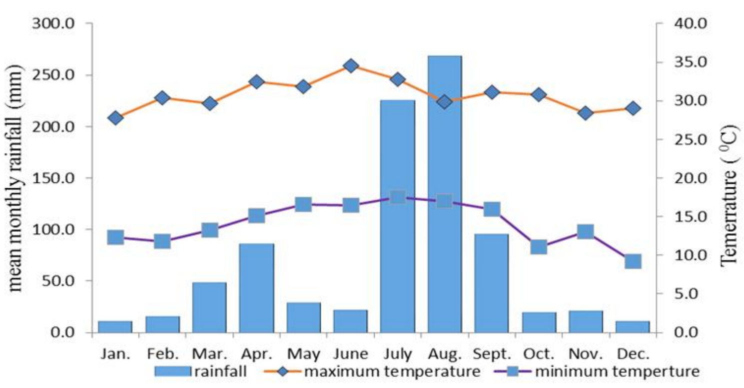

Fig. 2. Monthly average rainfall (mm) and mean max. and min. Temp. (°C) data of the study area (1990-2013 G.C)

to salinity and alkalinity problems. The pH and the electrical conductivity (EC) were measured using pH meter and electrical conductivity meter directly from the water samples. Soluble Cations of Ca^{2+} and Mg^{2+} in the water samples were determined directly from the water samples using atomic absorption spectrophotometer [7], while Na^{+} and K^{+} were determined in the same manner using flame photometer. Moreover, the anions like Cl^{-}, SO_4^{2-}, HCO_3^{-} and CO_3^{2-} in the water samples were determined following the procedures described for their respective determinations in the saturated soil paste extracts. The boron content of the water samples was determined by colorimetric estimation following the reaction of 98% sulphuric acid with 0.01% quinaizarine solution with the water sample [8].

Sodium adsorption ratio (SAR) of the water samples was computed as:

$$\mathrm{SAR_{iw}} = \frac{\mathrm{Na^+}}{\left[\frac{\mathrm{Ca^{2+} + Mg^{2+}}}{2}\right]^{1/2}}$$

Similarly, residual sodium carbonate (RSC) content of the water samples was computed from the concentrations of Ca^{2+}, Mg^{2+}, $HCO3^{-}$ and CO_3^{2-} ions by using the following formula:

$$RSC_{iw} = \left(CO_3^{\ 2-} + HCO_3^{\ -}\right) - \left(Ca^{2+} + Mg^{2+}\right)$$

3. RESULTS AND DICUSSION

3.1 Chemical Composition of Irrigation Waters of Cheffa Valley

To assess the salinity and sodicity related chemical properties of the irrigation (river and ground) waters within the study area, samples were taken from Borkena River Which is the potential source for irrigation and underground waters at profile excavation sites. The chemical compositions of the different irrigation waters taken from Borkena River and underground from each profile excavation site were presented in Table 1.

The pH values of ground waters increased from were 8.3, 8.1, 7.9, 8.2 and 8.0 at respective profiles 1, 2, 3, 4 and 5 respectively. In line with this the electrical conductivity (EC) of ground waters were 1.322, 0.997, 0.898, 0.964 and 0.895 dS m^{-1} correlated with the increment of pH values. This pH and EC value of ground waters implies that the ground waters in all of the profiles were highly saline which contribute salt development through capillary rise of soluble salts. On the other hand, the pH values of Borkena river water at different locations were ranging from 7.6 to 7.9 and the EC values ranging from 0.221-0.247 dS m^{-1} consistently with pH values. Hence, the pH and EC values of Borekena River indicate that, it was slightly alkaline according to US Salinity Laboratory Staff [4].

Similar finding on positive correlation between pH and EC pointed out by [9] on Dirma and Tulu Abajibo rivers and ground waters at Dirma Irrigation Project Site in South Wollo Zone of Amahara Regional Satate. Dissolved Na was dominant in all ground water samples ranging from 13.24 mmolc l^{-1} at the rainfed cultivated land (Profile 5) to 24.02 $mmol_c$ l^{-1} at the investor irrigated land (Profile 1) this higher concentration of soluble Na pointed out by [10] in irrigation water resources of Yellen Jewaha area in North Shoa Zone of Amhara Region.

The distribution of cations in the ground waters were dissolved Na^{+} and Ca^{2+} followed Mg^{2+} and K^{+} coupled with HCO_3^{-} and Cl^{-} anions. Hence, HCO_3^{-} and Cl^{-} salts of Na and Ca were dominant salts in the ground waters in all profiles of the study area. This result was in agreement with findings of [9] on ground waters of Dirma Irrigation Project in South Wollo Zone of Amhara Region. In contrary to ground water samples, the distribution of cations in River water samples were dissolved Na^{+} and Mg^{2+} followed by Ca^{2+} and K^{+} coupled with chloride and bicarbonate anions. Therefore, bicarbonate and chloride salts of sodium and magnesium were dominant salts in Borkena River. Therefore, the ground waters in all profiles excavated had high salinity hazard (C3) having EC in the in the range 0.75-2.25 dS m^{-1} and low sodicity hazard class (S1) waters but nearly to the medium (S2) range. While, the Borkena River water samples had medium salinity (C2) waters having EC in the range of 0.25-0.75 dS m^{-1} and low in sodicity hazard class (S1) water based on the classification of US Salinity Laboratory Staff [4].

Accordingly, the sodium adsorption ratio (SAR) value of underground waters was in the ranging from 8.21-12.54 from profile 5-1, respectively and the Borkena River water samples were in the range 1.65-2.15.

Table 1. Chemical compositions of irrigation water samples

Water source	pH	ECiw (dS m^{-1})	Soluble cations (mmol$_c$ l^{-1})				SAR	Soluble anions (mmol$_c$ l^{-1})				RSC	B (mg l^{-1})
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		SO_4^{2-}	HCO_3^{-}	CO_3^{2-}	Cl^{-}		
GW p1	8.3	1.322	4.55	2.78	24.02	0.21	12.54	0.96	3.51	0.11	3.23	-	0.112
GW p2	8.1	0.997	4.33	2.68	18.42	0.23	9.83	1.22	3.32	0.08	2.63	-	0.148
GW p3	7.9	0.898	3.61	2.43	16.61	1.61	9.58	1.49	1.82	0.13	4.15	-	0.173
GW p4	8.2	0.964	3.84	2.75	15.02	0.62	8.27	0.50	2.80	trace	2.63	-	0.189
GW p5	8.0	0.895	2.58	2.62	13.24	0.42	8.21	0.55	2.62	trace	3.14	-	0.197
BRw 1	7.9	0.247	0.71	1.39	2.64	0.32	2.15	1.21	2.34	0.15	4.27	0.39	1.230
BRw 2	7.6	0.221	1.63	1.54	2.39	0.68	1.65	1.6	3.26	0.13	3.51	0.90	1.140

GWp 1, 2, 3, 4 and 5 = Ground Water at profiles 1, 2, 3, 4, and 5; BRw 1, 2 = Borkena River Water at different site

Table 2. Suitability classes of irrigation water samples

Water source	ECiw (dS m^{-1})	Salinity hazard	SAR	Sodicity hazard	RSC	RSC class
GWp1	1.322	High (C3)	12.54	Medium(S2)	-	Safe
GWp2	0.997	High (C3)	9.83	Low(S1)	-	Safe
GWp3	0.898	High (C3)	9.58	Low(S1)	-	Safe
GWp4	0.964	High (C3)	8.27	Low(S1)	-	Safe
GWp5	0.895	High (C3)	8.21	Low(S1)	-	Safe
BRw 1	0.247	Medium (C2)	2.15	Low(S1)	0.39	Safe
BRw 2	0.221	Medium (C2)	1.65	Low(S1)	0.09	Safe

C=Salinity class; S= Sodicity class; RSC: Residual Sodium carbonate class

Regarding the boron concentration, boron in ground water samples was in the range 0.112-0.197 mg l^{-1}. According to boron toxicity level indicated by US Salinity Laboratory Staff [4], the concentration of B in ground water samples was excellent in boron hazard below the threshold value of toxicity level for sensitive crops, which was less than 0.33 mg l^{-1}. Hence, about boron toxicity the underground waters were safe for irrigation purpose about boron toxicity. However boron concentration the river water samples were ranging from 1.09-1.14 mg l^{-1}. Hence, concerning boron toxicity, the Borkena River water was poor for sensitive crops for irrigation purpose (Table 1).

3.2 Classification of Irrigation Waters

Based on EC, SAR and RSC values of ground and river water samples, the underground water samples investigated at profile 2, 3, 4 and 5 were high in soluble salt concentration (salinity hazard), low in sodicity hazard and safe in residual sodium carbonate hazard. High soluble salts concentration (salinity hazard), medium in sodicity hazard and safe in residual sodium carbonate hazard observed at in ground water at profile 1 [4]. Therefore, the current suitability classes of all the ground waters revealed that ground waters had not promising quality for irrigation purpose. However, Borkena River water had promising quality for irrigation in relation to salinity hazard, sodicity hazard, RSC hazard and B toxicity .Similar investigation also reported by [9] on Dirma and Tulu Abajibo River waters and ground waters at Dirma Irrigation Project in South Wollo Zone of Amhara Region.

Therefore, the ground water samples contained the high concentration of dissolved salts sufficient to change salt-free soils into saline and sodic conditions up on the continued uses of these water sources for irrigation or due to their contribution through capillary rise of dissolved salts. Almost similar findings pointed out by [9] in ground waters and Tulu Abajibo River water samples at Dirma Irrigation Project Site in South Wollo Zone of Amhara Regional State North Ethiopia and [11] on Awash River water at Fental Irrigation Project Site in Middle Awash Valley. Similar findings also reported on Awash River water at Matahara Sugar State Farm [12,13] in the Middle Awash Valley. Moreover, [10] also investigate medium salinity hazard class (C2) and low sodicity hazard (S1) water at Yellen Jewaha area in North Shoa Zone of Amhara region.

Thus, based on the criteria developed by US Salinity Laboratory Staff [4], both ground glasses of water at profile 2, 3, 4 and 5 and river water samples had low sodicity hazard (Table 2). However, ground water at Profile 1 had medium sodicity hazard. Concerning to the residual sodium carbonate hazard, both all ground waters investigated at all profiles and Borkena River were safe in residual sodium carbonate hazard.

4. CONCLUSION

Based on the results, it can be concluded that underground waters were high in soluble salt content, medium in sodicity and safe in residual sodium carbonate hazard while Borkena River is medium insoluble salt content, low in sodicity and safe in residual sodium carbonate hazard. Accordingly, the current result revealed that Borkena River is potentially suitable for irrigation purpose while utilization of underground waters for irrigation without treatment is aggravated salinity problem. Therefore, unless proper management practices were applied Soils of the area were prone to secondary salinization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. MoFED (Ministry of Finance and Economic Development). Ethiopa: Sustainable Development and Poverty Reduction Program. Addis Ababa. Ethiopia; 2002
2. International Monetary Fund (IMF). The Federal Democratic Republic of Ethiopia: Poverty Reduction Strategy Paper for the 2003/2004 Annual Progress. Country Report. 2006;6:27.
3. Ahmed, S. Effect of soil salinity on the yield and yield components of Mungbean. Pakistan Journal of Agronomy. 2009;4(1): 263-268.
4. Unite States of America Salinity Laboratory Staff. Diagnosis and improvement of Saline and Alkali soils. Hand Book 60, U.S Government Printing office, Washington, DC; 1954.

5. Heluf Gebrekidan. Investigation of salt-affected soils and irrigation water in Melka Sedi-Amibara Plain, Rift Valley Zone of Ethiopia. M.Sc Thesis, Addis Ababa University, Alemaya College of agriculture, Alemaya. 1985;132.
6. Rowell DL. Soil science: Methods and Applications. Longman Singapore Publishers Ltd. Singapore. 1997;350.
7. Reeuwijk LP. Procedures for Soil analysis. ISRICT technical Paper 9. 2002;120.
8. Wolg B. The determination of boron: soil extracts, plant materials, composts, manures, water and nutrient solutions. Soil Sci. Pl. Anal. 1971;2:263-287.
9. Hailu Getahun. Assessment of soils of irrigated lands and irrigation water quality concerning salinity and sodicity at Dirma areas os South Wollo Zone of Amhara Region, Msc Thesis, Haramaya University, Ethiopia. 2009;80.
10. Yonas Girma. Appraisal, spatial structure and mapping of soil salinity and irrigation *water* quality Yellen-Jewaha Areas in North Shewa zone of Amhara Region, MSc Thesis, Haramaya University, Ethiopia. 2005;65.
11. Kebenu Feyisa. Characterization of irrigated soils and irrigation water about salinity and sodicity: The Case of Fantale Irrigation Project Site in the middle Awash Valley, MSc Thesis Haramaya University, Ethiopia; 2011.
12. Girma Abejehu. Assesment of salinity and sodicity status of soils of Metahara Sugar Estate, Msc Thesis, Haramaya University, Ethiopia.1993;89.
13. Tena Alamirew. Spatial and temporal variability of Awash River water salinity and the contribution of soil salinization in the Awash Valley of Ethiopia. Doctorilal Dissertation, University of Natural resources and Apllied Life Sciences, Vienna. 2002;208.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24123