Characterization and Mapping of Salt Affected Soils and Irrigation Water Quality of Irrigated Lands in Raya-Alamata District, Northern Ethiopia

Birhane Hailu[1*], Hagos Mehari[1] and Bethel Nekir[2]
[1]*EIAR/ Mehoni Agricultural Research Center P. O. Box-2003, Addis Ababa, Ethiopia;*
[2]*EIAR/ Werer Agricultural Research Center P. O. Box-2003, Addis Ababa, Ethiopia*
Corresponding author email id:- birhane.hailu2011@gmail.com

Introduction

Salinity is one of the most devastating happened due to mismanagement of irrigation and aridity (Shahbaz and Ashraf, 2013). Assessment of salt affected soils is important for modern agricultural management, particularly for developing countries like Ethiopia, where agriculture is the main economic sector (Seleshi *et al*., 2007). Salt affected soils and the associated poor soil drainage conditions are the results from poor management of soils and irrigation systems (Tessema, 2011). Irrigation agriculture ensuring food security for billions of people in the past. However, their current and future state leaves much to be desired due to low crop yield and land degradation (Mason, 2002).The cultivated agricultural land of Ethiopia is about 12 million ha (MoA, 2011). Moreover, even if the potential and actual irrigated area is not precisely investigated (Belay and Bewket, 2013) estimates of irrigable land in Ethiopia averaged about 3.50 million ha (Seleshi *et al*., 2007). However, some irrigated lands face a problem of salinization due to mismanagement of irrigation system (Mohamed and Tessema, 2013).

Irrigation water quality is important since crop production mainly depends on irrigation in several arid regions in the world. Long-term application of ground water of moderate to low quality in poorly drained land may accumulate high quantity of salts in the agricultural land (Abdulaziz *et al*., 2003). Therefore, irrigation water quality should be evaluated before implementation of irrigation projects (Al-Ghobari, 2011).

Physical observation and available information of soils on the recently initiated small scale irrigation schemes and groundwater sources in Tigray region show accumulation of soluble salts (Kidane *et al.*, 2006). Farms under irrigation require a periodic evaluation of soil salinity/sodicity and irrigation water quality so as to adjust future production for a given area. This is particularly important in southern zone of Tigray, Raya Alamata district, where poor land and water management is encountered. In response this, a study was conducted to characterize the salinity/sodicity status of soils of irrigated lands and irrigation water quality of Raya Alamata district.

Materials and Methods

Description of the District

The study was conducted in southern zone of Tigray Raya Alamata district, northern Ethiopia at two irrigated sites, namely Tumuga and Gerjale. The district is located at 600 km north of Addis Ababa (IPMS-ILRI, 2005) and geographically located between 12°25' and 12°55' North latitudes and 39°33' and 39° 53' East longitudes with an elevation of 1520 meter above sea level (REST, 1998). The major soil types found in the district are Cambisols, Fluvisols, Leptosols and Vertisols. The landform of the district is largely level plain where Vertisols and Fluvisols are the dominant and found extensively in farmlands (Amanuel *et al.*, 2015).

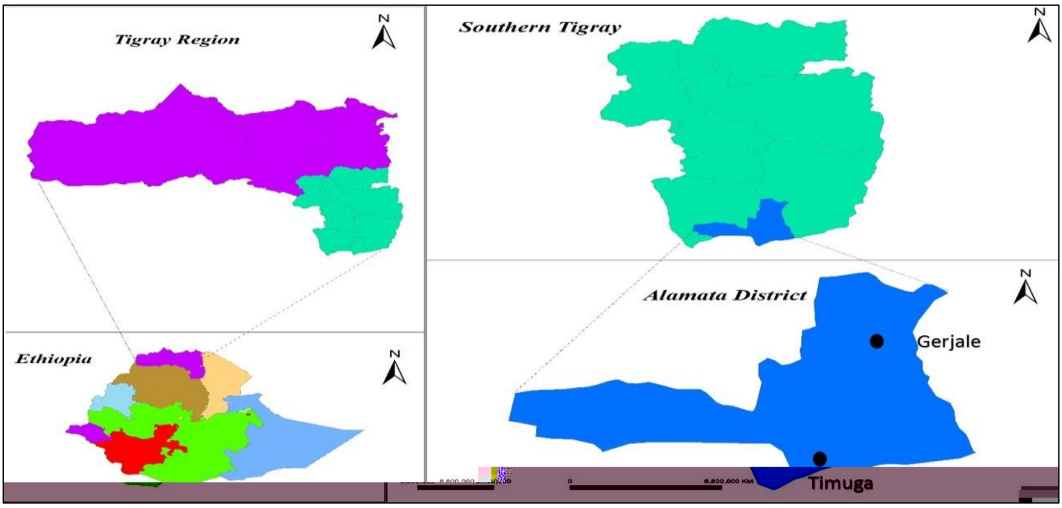

Figure 1. Location map of the study area

Raya Alamata district has a bimodal rainfall pattern, annual rainfall (mm), minimum and maximum temperatures (^{0}C) collected from National Meteorology Service Agency (1997-2018) show that it is 637.31, 15.71 and 27.85, respectively. The district area experiences a short rainy season locally known as *Belg* which runs from February to April followed by the main rainy season called *Kiremt* which runs from June to early September (REST, 1996).

Soil Sample Collection and Method of Sampling

General visual field reconnaissance survey was carried out in the study area to have a general view of the variations/homogeneity of the study area by traversing walk in the field. Based on the observation, the field was divided in to a number of sampling units based on similarities of surface soil color, drainage condition, land use system, vegetation cover, slope and cropping history of the district and then sampling points were selected from each of the demarcated sampling units. Soil sample collection was conducted during the months of November and December 2018. Accordingly, soil samples from two depths (0-30 cm) using Augur (Wilding, 1985). All sampling points were geo-referenced using global positioning system (GPS) and sampling dates were properly recorded.

Soil sample preparation and Analysis

The collected soil samples were air-dried, ground to pass through 2 mm sieve and prepared for the determination of soil salinity/sodicity indicators and selected soil physico-chemical properties**.** Soil pHe was measured potentiometrically using a digital pH-meter and ECe by digital conductivity meter according to the methods stated by USSLS (1954). Both exchangeable (Ca and Mg) and water soluble ($Ca^{2+}$and Mg^{2+}) were determined by Atomic Absorption Spectrophotometer (AAS) and exchangeable (Na and K) and water soluble (Na^{+} and K^{+}) were determined by flame photometer. The cation exchange capacity (CEC) of the soils was determined by the neutral normal ammonium acetate method according to the percolation tube procedure (Van Reeuwijk, 1992). Exchangeable sodium percentage (ESP) was computed as the percentage of the exchangeable Na to the cation exchange capacity (CEC) of the soil.

$$ESP(\%) = \frac{\text{Exchangeable sodium (Na)}}{CEC} * 100$$

Where, concentrations were expressed in cmol (+) kg^{-1} of soil.

Analytical results of soil reaction (pHe), electrical conductivity of the saturation paste extract (ECe), sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) of the soil solution were used as important parameters to explain salinity/sodicity characteristics of the soil. Three classes of salt affected soils were defined based on their chemical properties, accounting for changes in ECe, pHe, and ESP. Accordingly, a threshold value of 4 dS m^{-1} ECe was used to differentiate between saline and non-saline soils. Similarly, a threshold value of, 15 % for ESP and 8.5 for pHe were used as criteria for grouping the soils in to different classes of salt affected soils (USSLS, 1954).

However, a survey of published data (FAO, 1988) showed that, for sodic soils most often an ESP of 15% is associated with a saturation paste pH of 8.2 and ECe threshold value of 4 dS m^{-1} were used by excluding the value of sodium adsorption ratio. For classifying sodic soils therefore, a saturation paste pH of 8.2 was used as suggested by (FAO, 1988) to be more realistic than the value of 8.5 which is nearly always associated with higher values of exchangeable sodium percentage.

Irrigation Water Sample Collection and Methods of Sampling

Prior to irrigation water sampling, field survey was carried out. Based on the field observation, irrigation water sampling sources were selected. Accordingly, samples were taken from the selected sources (ground and surface water) and irrigation canals using plastic bottles. Each sample was numbered and labeled carefully and placed in to boxes with location and sources indicated. The sources of irrigation water sampling points were geo-referenced using GPS.

Analysis of Selected Irrigation Water Quality Parameters

Electrical conductivity and pH of the water samples were measured using conductivity meter and a digital pH meter, respectively (USSLS, 1954). Ca^{2+} and Mg^{2+} of the irrigation water samples were directly measured using AAS, while Na^{+} and K^{+} were analyzed using flame photometer. Similarly, the anions (CO_3^{2-}, HCO_3^{-}, Cl^{-} and SO_4^{2-}) of the irrigation water samples were determined following the standard procedures. Boron (B) was determined following Curcumin analytical method as outlined by Dible *et al.* (1954). Irrigation water salinity, as total dissolved salts (TDS) was determined by summing the concentrations of the individual ions (Bryan *et al*., 2007). The residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) were determined from the concentrations of HCO_3^{-}, CO_3^{2-}, Na^{+}, Ca^{2+} and Mg^{2+} using (USSLS, 1954). Mapping was done using cricking method.

Results and Discussion

Selected Soil Chemical Properties

Soil reaction (pHe) and electrical conductivity (ECe)

The analytical results of soil reaction (pHe) from saturated paste extract ranged from 7.53 to 8.71 and from 7.55 to 8.21 at Tumuga and Gerjale sites, respectively. The average value of pHe were 8.05 at Tumuga and 7.94 at Gerjale. The highest (8.71) and the lowest (7.53) soil pHe values were recorded at Tumuga site of the district. According to the rating of Jones (2003), soil pHe of the surface soil under investigation was rated from slightly alkaline to strongly alkaline range (Jones, 2003). The same rating of pHe was reported by Amanuel *et al. (*2015) for the soils of the district and revealed that, this range of pHe value may have effect on nutrient availability. In general, the probable reason for the higher soil pHe values could be due to relative abundance of alkaline forming cations. In addition to this, the district had high evapotranspiration rate and low soil moisture, causing accumulation of basic cations at the surface soil and result in higher soil pHe as outlined by Amanuel *et al.* (2015).

Table 1. Area coverage per soil reaction (pHe) of the two sites

Soil pH value	Spatial analysis (%)		Soil reaction class
	Tumuga	Gerjale	
<7.53	0.00	11.46	Slightly alkaline
7.88-8.0	7.69	59.79	Moderately alkaline
8.01-8.2	62.57	28.65	Moderately alkaline
8.21-8.4	23.77	0.00	Moderately alkaline
8.41- 8.6	0.88	0.00	Strongly alkaline

The total calculated sampling area of the district were 3545.82 ha for Tumuga and 3122.94 ha for Gerjale site. The laboratory analysis result and ARC GIS map showed that, high pH value was recorded at Tumuga site than that of Gerjale site. This is because of that, high accumulation of basic cations were observed in in Tumuga site. According to the spatial analysis, Tumuga site was rated moderately alkaline to strongly alkaline whereas, Gerjale site was rated from slightly alkaline to moderate alkaline (Table 1) with respect to pHe values.

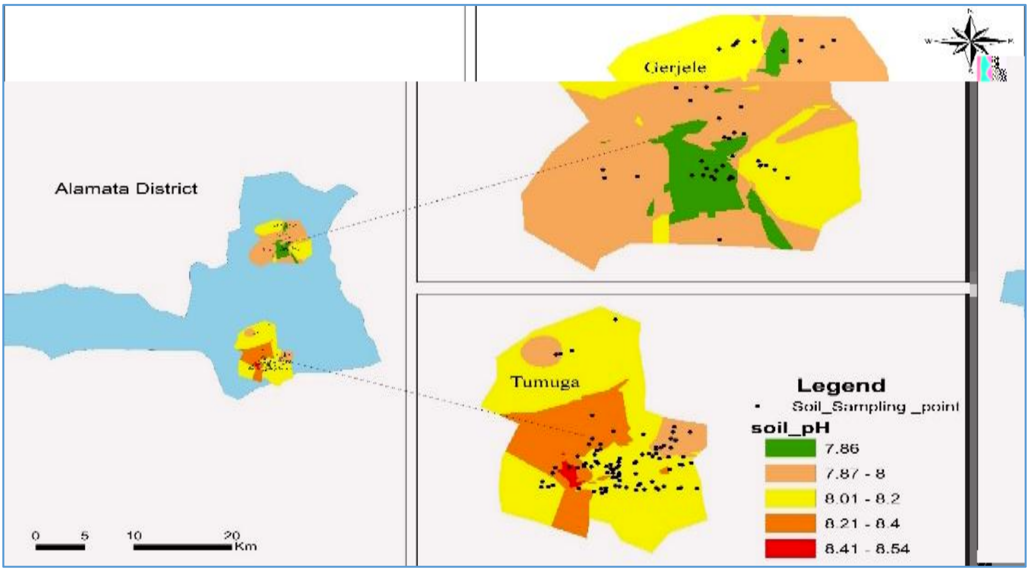

Figure 2. Map of spatial distribution in soil reaction.

The surface soil of the district exhibited high variation with respect to ECe values for both sites. Accordingly, ECe values varied from 0.34 dS m^{-1} to 7.43 dS m^{-1} and from 0.25 dS m^{-1} to 8.26 dS m^{-1} at Tumuga and Gerjale sites respectively. This could be due to the reason that, salt concentration in soils may vary greatly with sampling spot, sampling unit and horizontal or vertical distance (Achalu *et al.*, 2012). Frew *et al.* (2015) also indicated that soils of Melka Sedi and Melka Werer areas of Afar region irrigated farms exhibited high variation with respect to

ECe values. Indeed, there is the problem of water logging and drainage condition that can contribute to the salinity in the district.

Table 2. Area coverage per ECe (dS m^{-1}) levels of the two sites.

ECe (ds/m)	Spatial analysis (%)	
	Tumuga	Gerjele
<1	66.44	30.72
1-2	26.54	20.28
2-4	1.86	37.32
4-8	5.13	11.67
8-16	0.00	0.00

The laboratory analysis result and ARC GIS map showed that, 5.13% and 11.67% at Tumuga and Gerjale sites respectively were covered with high ECe (>4 dS m^{-1}) values. Similarly, 66.44% at Tumuga and 30.72% at Gerjale site were covered with low ECe (<1 dS m^{-1}) values. This showed that based on the classification of ECe, more of the total area under consideration were free of ECe (>4 dS m^{-1}) values. Out of the total area under consideration, high ECe values were recorded at Gerjale site than at Tumuga site (Table 2).

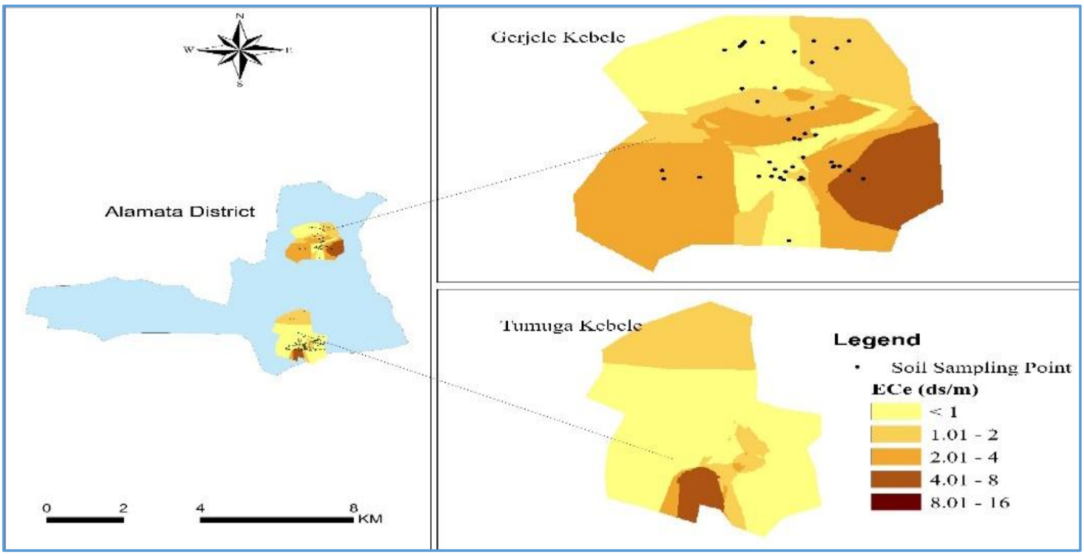

Figure 3. Map of spatial distribution in soil Electrical Conductivity.

Exchangeable sodium percentage

Exchangeable sodium percentage (ESP) ranged from 0.58% to 28.11% and 0.49% to 13.70% in Tumuga and Gerjale sites, respectively. The overall laboratory analysis result and ARC GIS map revealed that, 4.88% of the total area was covered with high ESP (>15%) value at Tumuga site while, low value of ESP (<15%) was recorded at Gerjale site. This showed that based on the classification of ESP, Gerjale site is free from exchangeable sodium percentage. Out of the total area under consideration, high ESP values were recorded at Tumuga site than at Gerjale site (Table 3).

Table 3. Area coverage per ESP levels of the two sites.

ESP (%)	Spatial analysis (%)	
	Tumuga	Gerjale
<5	79.18	82.7
5-10	13.95	17.3
10-15	1.88	0.0
15-20	4.88	0.0
20-25	0.07	0.0

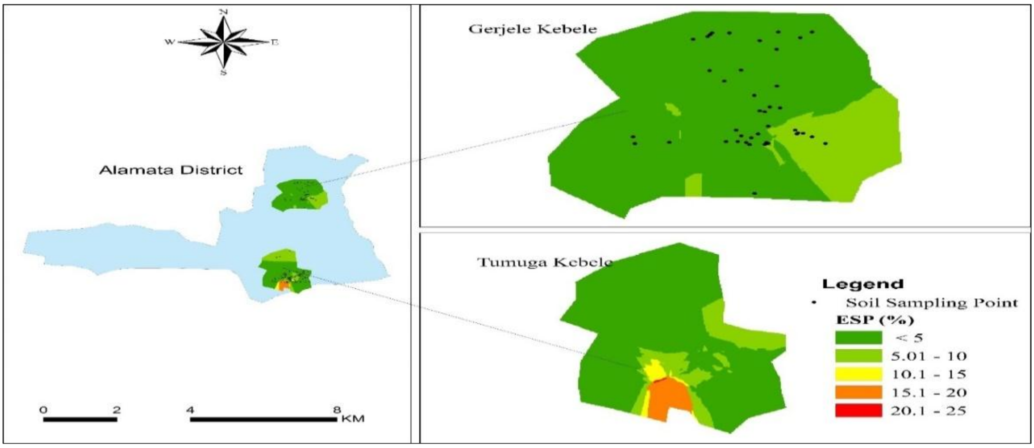

Figure 4. Map of spatial distribution in soil exchangeable sodium percentage.

Soil Salinity/Sodicity Status of the district

According to the published classification system of the FAO (1988), and using laboratory analysis result and ARC GIS map with respect to ECe, ESP and pHe values, out of the total area under consideration, 5.13% (182 ha) and 11.67% (364.5 ha) were rated as saline soils in Tumuga and Gerjale sites respectively (Table 4).

Table 4. Area coverage of surface (0-30 cm) salt affected soil classes

No.	Salt affected soil classes	Tumuga (Spatial analysis in ha and %)	
		Area (ha)	Area (%)
1	Normal	3182.02	89.74
2	Saline	181.90	5.13
3	Sodic	6.03	0.17
4	Saline sodic	175.87	4.96
	Total area (**ha**)	3545.82	100
	Gerjale (Spatial analysis in ha and %)		
1	Normal	2758.49	88.33
2	Saline	364.46	11.67
3	Sodic	0.00	0.00
4	Saline sodic	0.00	0.00
	Total area (**ha**)	**3122.94**	100

Similarly, 4.96% (176 ha) and 0.17% (6.03 ha) were covered with saline sodic and sodic soils at Tumuga site respectively. The remaining 89.74% (3182 ha) at Tumuga and 88.32% (2758.18 ha) at Gerjale sites were free from salt. With regarding to Gerjale site normal and saline soil cover 88.32% and 11.67 %, respectively, this showed that Gerjale site is free from exchangeable sodium percentage (Table 4).

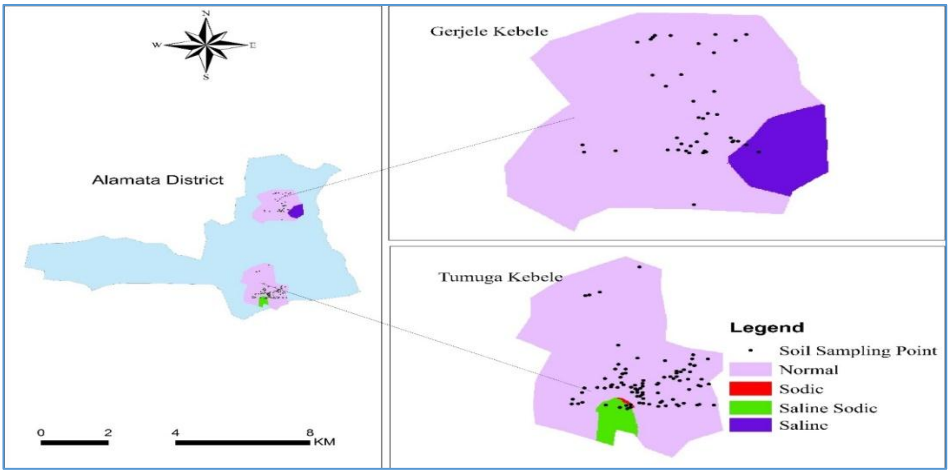

Figure 5. Map of spatial distribution of surface salt affected soils in Tumuga and Gerjale sites.

Chemical Composition of Irrigation Water

pH and ECw of Irrigation Water

The result of the laboratory analysis indicated that the pH of the irrigation water varied from 7.59 to 8.82 and 7.60 to 8.63 at Tumuga and Gerjale sites, respectively (Table 7). Irrigation water tends to be alkaline commonly in the range of pH 7.2 to 8.5. As irrigation water pH increases above 8.2, the potential for sodium problem increases and destroys the structure of the soil (Bryan *et al*,. 2007). Based on the same author classification, the irrigation water analytical results showed that, the average values of pH were 8.15 and 7.91 at Tumuga and Gerjale sites, respectively. Therefore, the irrigation water quality of the study area classified as slight to moderate and severe in degree of restriction to use (potential irrigation problem) with regard to pH values (Bryan *et al*., 2007).

Electrical conductivity of irrigation water (ECw) values ranged from 0.13 to 0.37 dSm^{-1} at Tumuga and from 0.07 to 0.34 dSm^{-1} at Gerjale site (Table 7). According to USSLS (1954) and FAO (1985) classification, the irrigation water quality of the study area classified as class one (C1) which is low salinity hazard except one sample from Gerjale site having an ECw value of 0.34 dSm^{-1} and one sample from Tumuga having an ECw value of 0.37 $dS\ m^{-1}$ which were both classified as class two (C2) or medium salinity hazard (USSLS (1954). The maximum ECw value of irrigation water at both sites were found at the maximum corresponding values of Na^+ and Cl^- which is in agreement with Mali *et al*.(2012).

Major Ionic Concentrations in Irrigation Water

Among the cations, Mg^{+2} was dominant followed by Ca^{+2}, Na^+ and k^+ at Tumuga site respectively, while, Ca^{+2} was dominant in Gerjale site followed by Mg^{+2}, Na^+ and K^+ respectively. Among the anions, HCO_3^- was dominant followed by Cl^-, CO_3^{-2} and SO_4^{-2} at both sites (Table 7). However, CO_3^{2-} was present in few water samples. This presence of CO_3^{-2} in few water samples were also reported by Muhammad *et al*. (2013). According to FAO (1988), based on degree of restriction to use for their Cl^- (surface irrigation), all the water samples were classified as none (no problem) except one sample classified as slight to moderate problem at Tumuga site. Similarly, all irrigation water samples were classified as slight to moderate problem based on their degree of restriction to use with regard to HCO_3^- (FAO, 1988). The concentration of Boron (Table 7) was found to be in a smaller amount. Thus, according to USSLS (1954), the concentration of boron were below the standard set for the toxicity level of sensitive crops.

Sodium Adsorption Ratio, Residual Sodium Carbonate and TDS

The sodium adsorption ration (SAR) of the irrigation water ranged from 0.19 to 3.28 at Tumuga and 0.25 to 4.95 at Gerjale sites (Table 7). According to USSLS (1954), irrigation waters having SAR < 10 is good for irrigation. Therefore, it was observed that irrigation water at both sites was suitable for irrigation purposes with regard to SAR (USSLS, 1954). In SAR, the Ca^{2+} and Mg^{2+} ions are important since they tend to counter the effects of Na^+ hazard. The concentration of Ca^{+2} and Mg^{+2} were higher in the irrigation water at both sites relative to Na^+ (Table 7) and enough to counter the effect of Na^+ hazard. Dhembare (2012) reported that the dominance of Ca^{2+} and Mg^{2+} in irrigation water tends to counter the effects of Na^+ hazard.

The residual sodium carbonate (RSC) values of irrigation water in the study area ranged from trace to 2.98 meq L^{-1} at Tumuga and from trace to 3.09 meq L^{-1} at Gerjale (Table 7). The maximum (3.09 meq L^{-1}) value of RSC were recorded at Gerjale site. The trace values of RSC were due to non-presence of CO_3^{2-} in some irrigation water samples. However, the water was suitable for irrigation from RSC point of view (Dhembare, 2012). The dominance of the sum of Ca^{2+} and Mg^{2+} over the sum of CO_3^{2-} and HCO_3^- was reflected in the trace values of RSC in this specific irrigation water quality of the district.

According to USSLS (1954), only one irrigation water sample from each site was classified as unsafe (high) with regards to RSC (USSLS, 1954). Therefore, among the irrigation water samples with regard to RSC, 85.71% and 87.50% were suitable and 14.29% and 12.5% were not suitable for irrigation purpose at Tumuga and Gerjale sites, respectively.

Irrigation water salinity, as total dissolved salts (TDS) was calculated by summing all the concentrations of the individual water soluble cations and anions of the irrigation water as outlined by Bryan *et al*. (2007). Accordingly, TDS value ranges from 674.17 to 1204.87 mg L^{-1} at Tumuga and 408.21 to 1215.41 mg L^{-1} at Gerjale (Table 7). The maximum and minimum TDS value were recorded at Gerjele site. Based on degree of restriction set by FAO (1988) on use of water for irrigation, the concentration of TDS were classified under slight to moderate (450 - 2000 mg L^{-1}) in their potential problem (FAO, 1988). Therefore, major salinity problem is expected from irrigation water if proper management is not conducted.

Table 7. Chemical compositions of irrigation water sources in the district

Sample source	pH	ECw (dS m^{-1})	Dissolved Cations (meq L^{-l})				SAR	Dissolved Anions (meq L^{-l})				B(mg L^{-1})	RSC (meq L^{-l})	TDS (mg L^{-1})
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}			
Tumuga Irrigation Water Quality														
Surface	7.59	0.16	4.76	5.05	0.43	0.03	0.19	Trace	7.00	0.06	3.50	0.04	Trace	723.68
Surface	7.78	0.14	4.36	5.76	1.88	0.04	0.84	Trace	8.00	0.04	3.30	0.23	Trace	811.04
Surface	8.48	0.37	3.19	5.33	6.77	0.50	3.28	Trace	11.50	0.28	5.20	0.27	2.98	1204.87
Canal	8.10	0.13	3.09	4.68	2.07	0.04	1.05	1.20	6.80	0.02	2.30	0.18	0.23	702.69
Canal	8.82	0.16	1.39	6.34	3.53	0.06	1.80	2.00	6.60	0.05	2.80	0.16	0.87	753.50
Surface	8.10	0.13	3.68	4.59	1.44	0.07	0.71	0.40	6.60	0.08	2.50	0.27	Trace	674.17
Canal	8.18	0.20	3.70	6.54	3.53	0.07	1.56	2.20	7.90	0.07	3.90	0.09	Trace	928.66
Mean	**8.15**	**0.18**	**3.45**	**5.47**	**2.81**	**0.12**	**1.35**	**1.45**	**7.77**	**0.09**	**3.36**	**0.18**	**1.36**	**828.37**
Gerjale Irrigation Water Quality														
Canal	7.60	0.09	4.46	2.42	0.47	0.03	0.25	Trace	5.10	0.03	1.70	0.15	Trace	505.42
Ground	8.63	0.34	3.56	3.55	9.34	0.41	4.95	Trace	10.20	0.25	6.60	0.42	3.09	1215.41
Ground	7.78	0.09	2.38	2.58	0.62	0.03	0.39	0.60	5.20	0.01	1.80	0.19	0.84	495.11
Ground	7.95	0.07	2.90	1.80	0.91	0.03	0.59	0.40	4.60	0.00	1.60	0.13	0.30	452.66
Ground	8.00	0.08	3.72	2.10	0.91	0.03	0.53	0.60	4.50	0.02	1.50	0.05	Trace	470.27
Ground	7.98	0.07	3.73	1.89	0.81	0.03	0.48	0.80	3.70	0.01	1.10	0.11	Trace	408.21
Ground	7.70	0.09	4.66	2.54	0.72	0.03	0.38	0.60	5.20	0.03	1.80	0.02	Trace	544.22
Canal	7.60	0.09	4.48	2.57	0.62	0.08	0.33	0.60	5.30	0.04	1.60	0.28	Trace	540.32
Mean	**7.91**	**0.12**	**3.74**	**2.43**	**1.80**	**0.08**	**0.99**	**0.60**	**5.48**	**0.05**	**2.21**	**0.17**	**1.41**	**578.95**

ECw = Electrical conductivity of irrigation water; SAR= Sodium adsorption ratio; RSC= Residual sodium carbonate; TDS= Total dissolved salts.

Conclusion and Recommendation

Accordingly, pHe of the surface soil was rated from moderately alkaline to strongly. The pHe values of the irrigated lands slightly increased with depth. The geospatial analysis result of implies out of the total area under consideration, 5.13% (182 ha) and 11.67% (364.5 ha) were rated as saline soils in Tumuga and Gerjale sites, respectively. Similarly, 4.96% (176 ha) and 0.17% (6.03 ha) were mapped as saline sodic and sodic soils at Tumuga site, respectively.

All sites of irrigation water were good for irrigation purposes with regard to SAR. The RSC indicated that, 85.71% and 87.50% were suitable and 14.29% and 12.50% were not suitable for irrigation purpose at Tumuga and Gerjale sites, respectively. Boron and TDS were below the standard set for the toxicity level of sensitive crops and slight to moderate in their potential irrigation problems, respectively. The probable cause of soil salinity/sodicity was the shallow ground water depth. Indeed, irrigation water with maximum ECw could also be the cause for the salinity problem. As a result, continuous assessment and monitoring should be implemented to avoid the occurrence of soil salinity/sodicity problems. Moreover, selection of suitable plant varieties that can tolerate soil salinity and extract the amount of perched water near the surface to lower the shallow ground water table is mandatory.

References

Abdulaziz M., Al-Bassam M, Yousef A and Al-Rumikhani H. 2003. Integrated hydro-chemical method of water quality assessment for irrigation in arid areas: application to the Jilh aquifer. *Journal of Saudi Arabia*, 36(25): 345–356.

Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadesse. 2012. Status of selected physico-chemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences,* 2(3): 57-71.

Al-Ghobari, H. 2011. Effect of Irrigation Water Quality on Soil Salinity and Application Uniformity under Center Pivot Systems in Arid Region. *Australian Journal of Basic Applied Science,* 22(5): 72-80.

Allotey F, Asiamah D, Dedzoe D and Nyamekye L. 2008. Physico- Chemical Properties of Three Salt-Affected Soils in the Lower Volta Basin and Management Strategies for their Sustainable Utilization. *West African Journal of Applied Ecology,* 12(3):23-29.

Amanuel Zenebe, Girmay Gebresamuel and Atkilt Girma. 2015. *Characterization of Agricultural Soils in CASCAPE Intervention Woredas in Tigray Region.* Mekelle, 58-64.

Belay Mehretie and Bewket Woldeamlak. 2013. *Traditional Irrigation and Water Management Practices in Highland Ethiopia:* Case Study in Dangila Woreda, Irrigation and Drainage, 62: 435- 448.

Dhembare J. 2012. Assessment of Water Quality Indices for Irrigation of Dynaneshwar Dam Ahmednagar, Maharashtra, India. *Archives of Applied Science Research*, 4 (1):348-352.

Dible T, Truog E and Berger C. 1954. Boron determination in soils and plants. *Analytical Chemistry*, *26*(2): 418-421.

FAO (Food and Agricultural Organization). 1985. *Water Quality for Agriculture*. Irrigation and Drainage Paper 29, Rome.

FAO (Food and Agricultural Organization). 1988. *Salt Affected Soils and Their Management.* FAO Soils Bulletin 39, Rome, Italy.

Frew Abebe, Tena Alamrew and Fentaw Abegaz. 2015. Appraisal and mapping of soil salinity problems in Amibara irrigation farms , middle awash basin, Ethiopia. *International Journal of Innovation and Scientific Research*, 13(1): 298-314.

Heluf Gebrekidan. 1985. Investigation on salt affected soils and irrigation water quality in Melka Sedi-Amibara Plain, Rift Valley Zone of Ethiopia. MSc. Thesis presented to the School of graduate Studies of Addis Ababa University.131.

Hillel D. 1980. *Fundamentals of Soil Physics*. Academic Press, Inc., London.

IPMS-ILRI (Improved Productivity and Market Success-International Livestock Research Institution). 2005. Alamata pilot learning site diagnosis and program design, Tigray, Ethiopia.

Jones J. 2003. *Agronomic Hand Book:* management of crops, soils and their fertility, Washington DC.

Kidane Georgis, Abebe Fanta, Heluf Gebrekidan, Fentaw Abegaz, Wondimagegne Chekol, Hibstu Azeze , Asegid Ayalew, Messele Fisseha, and Mohammed Bedel. 2006. Report of the National Task Force on Assessment of Salt Affected Soils and Recommendations on Management Options for Sustainable Utilization.

Mali B, Thengal S and Pate N. 2012. Physico - chemical characteristics of salt affected soil from Barhanpur, M.S., India. *Annals of Biological Research,* 3 (8): 4091-4093.

Mason C. 2002. *Biology of fresh water pollution.4th ed*. Pearson Prentice Hall. Amazon New York Series, Great Britain.

MoA (Ministry of Agriculture). 2011. *Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment.* Addis Ababa, Ethiopia.

Mohamed Seid and Tessema Genenew. 2013. Evaluation of soil and water salinity for irrigation in North-eastern Ethiopia: Case study of Fursa small scale irrigation system in Awash River Basin. *African Journal of Environmental Science*, 7(5) :167-174.

Muhammad A, Muhammad N, Muhammad K and Farah U. 2013. Characterization of Ground Water Quality for Irrigation in Tehsil District, Punjab Pakistan. *Nature and Science,* 11(4): 128-132.

REST (Relief Society of Tigray).1996. *Raya Valley Development Study Project,* Phase I Reconnaissance report, Mekelle, Ethiopia.

REST (Relief Society of Tigray). 1997. *Feasibility Study report for the Raya Valley Agricultural Development.* Volume I.

REST (Relief Society of Tigray). 1998. *Feasibility Study report, for the Raya Valley Agricultural Development*. Volume III, Agriculture.

Seleshi Bekele, Aster Denekew, Makonnen Loulseged, Loiskandl W, Mekonnen Ayana and Tena Alamirew. 2007. *Water Resources and Irrigation Development in Ethiopia*. Working Paper 123, Colombo, Sri Lanka, International Water Management Institute, 78.

Shahbaz M and Ashraf, M. 2013. Improving salinity tolerance in cereals. *Review of Plant Science,* 32(19): 237–249.

Tessema Genenew. 2011. *Management of Salt Affected Soils*. Soil Analysis for Soil Salinity and Fertility Status. VDM Publishing House Ltd.Verlag and Co.KG. Germany, 84.

USSLS (United State Salinity Laboratory Staff). 1954. *Diagnosis and improvement of saline and alkali soils.* Agriculture Hand book 60, USDA, Washington DC.

Van-Reeuwijk L. 1992. *Procedures for soil analysis*. 3rd *ed*. International Soil Reference and Information Center, Wageningen, the Netherlands, *34.*

Wilding L. 1985. *Soil spatial variability: Its documentation, accommodation and implication to soil surveys*. *166-187.*