Evaluation of Surface and Ground Water Quality for Irrigated Agriculture in Ziway Area

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ABSTRACT

Irrigation water, irrespective of its source, contains a great deal of harmful substances that may reduce crop yield and deteriorate soil quality. The quality of available water sources, in this regard, should be evaluated before using them for irrigation purposes. Therefore, this study was aimed at assessing the quality of irrigation water that farmers used in the area and suggesting possible management options. A total of 24 water samples were collected from 4 extensively used bore holes and 2 abstraction points along the Bulublla River in 2016 and 2017. Fourteen quality parameters were applied following standard laboratory procedures. General linear model of two ways analysis of variance was used to evaluate quality parameters across the locations and water sources. The results revealed that about 64.3% of the parameters showed remarkable variation at $P<0.05$ across water sources while 35.7% showed variation across locations. Moreover, about 93% of the quality parameters showed higher values in groundwater samples compared to surface water. This suggests that the quality of groundwater would be an issue in the area. Sodium adsorption ratios in all locations were found within acceptable limits for irrigation, but its highest value was observed in groundwater samples. Other secondary water quality indices had also remained very high in ground water samples. Thus, paying attention to the quality of groundwater was very important to maintain soil productivity. In general, all crops could be grown effectively with the assessed water sources. However, management practices such as; fallowing, conjunctive use of both sources and choice of salt tolerant crops might help to maximize yield if crops were irrigated with groundwater.

Keywords: Irrigation; permissible limits; quality indices; suitability; water sources

1. INTRODUCTION

Amid increasing impacts of climate change and surging food demand makes irrigated agriculture an important area of intervention. FAO (2017) reported that every year more than ten million people faced food shortage problems in dry parts of Ethiopia. This could be attributed to climate variability and extreme weather conditions that occurred during cropping seasons (Mesfin, 2015; FAO, 2017). Different researchers regarded the prevalence of extreme weather conditions in dry regions as a major risk factor that might affect crop production (Abel et al. 2014; Husien et al. 2017; Hadera, 2018). CSA (2017) report indicated that the majority of farmers in Ziway area were highly dependent on rainfall to cultivate food crops. Such situations might have made the livelihood of the farming communities extremely vulnerable to changes in weather conditions. Hence, employing irrigation practice was found to be a key factor to fix the problems associated with the variability of weather conditions.

Central Rift Valley Lakes Basin in Ethiopia is well known for the shortage of rainfall, but suitable for irrigation using surface and/or groundwater (Legesse and Ayenew, 2006; Halcrow, 2008). Edossa et al. (2014) and Kefyalew and Kibebew (2016) noted that agricultural activities are the most dominant form of economic activity in the area to support the livelihood of the inhabitants. Despite these facts, the agricultural production system is traditional and characterized by a low level of technologies such as seeds and irrigation facilities. However, in recent times both Federal and Regional governments are giving due attention to improving irrigation practices. Several authors argued that irrigation practices allow smallholders to diversify cropping patterns and reduce the risks associated with rain-fed agriculture (Edossa et al. 2014; Nagaraju et al. 2014; Kefyalew and Kibebew, 2016; Qureshi et al. 2018).

In this regard, water quality becomes a crucial issue if irrigation is to be used for crop production. Abel et al. (2014) and Abay et al. (2016) stressed that irrigated agriculture is highly dependent on adequate supply of quality water. Ayers and Westcot (1985) reported that early day's water quality was neglected because good quality water supplies had been plentiful and readily available. However, this situation is now changing in many parts of the world because of the intensive use of water for irrigation to provide enough food items for the ever-increasing population (Adamu, 2013; Nagaraju et al. 2014). Pascual-Ferrer et al. (2014) and Mesfin (2015) also indicated that the demand for irrigation in the present study basin shows an increasing trend over time. This situation may affect the supply of good quality water for irrigation activities in the area. Avoiding problems associated with water supplies for irrigation requires sound planning to ensure the availability of water sources for productive use.

Adamu (2013), Kefyalew and Kibebew (2016), and Hadera (2018) observed that the quality of water used for irrigation may have an impact on the characteristics of the soil. Thus, prior evaluation of its suitability for irrigation becomes an important approach to reduce its influences on soil quality. The increasing need for water by different sectors may constrain the supply of quality water for the irrigation sector. Legesse and Ayenew (2006) and Awulachew et al. (2007) reported that irrigation activities have to compete for the available water sources with other sectors. This signifies how the scarcity of quality water may threaten the practice of irrigated agriculture in such areas. This situation may make producers use undesirable water sources for irrigation purposes. As a result, most of the irrigated fields could be affected by salinity and sodality that deteriorate soil fertility and ultimately decrease crop yield.

Ayers and Westcot (1985) and Hillel (2000) noted that irrigation water may contain impurities in the form of dissolved and sometimes suspended materials. The amounts of these materials under given environmental conditions determine the quality of irrigation water. Hence, the evaluation of irrigation water quality across the source at a certain time interval is very important to maintain the productivity of cropping lands (Reddy, 2013; Islam et al. 2016). Besides, assessing the quality of irrigation water may support to develop strategies for appropriate on-farm water management practices. Some works on irrigation water quality analysis were done in the present study area (Mesfin, 2001, Halcrow, 2008; Pascual-Ferrer et al. 2014; Abay et al. 2016; Hadera, 2018). However, these works were more general and failed to consider site-specific irrigation water quality issues across different sources. Therefore, the main objectives of this study were to; i) assess the variability of irrigation water quality across the sources and locations; ii) determine water quality suitability for irrigation and iii) suggest possible management options related to its limitations.

2. MATERIALS AND METHODS

2.1. Descriptions of the study area

2.1.1. Location

The study area is located in Adamitulu district in the South Western Shewa Zone of the Oromiya Regional State of Ethiopia (Figure 1). Geographically, the area extends from 7° 50' 00" to 7° 53' 57" N latitude and from 38° 42' 00" to 38° 46' 00" E longitude. It is located in the Central Rift Valley region about 160 km south of Addis Ababa, just at the lower end of Lake Ziway. The study village has more than 760 households that are dependent on a mixed crop-livestock production system. The altitude of the study area is ranging from 1600 to 1700 masl in the tropical semi-arid zone in the middle part of the Ethiopian Rift Valley system.

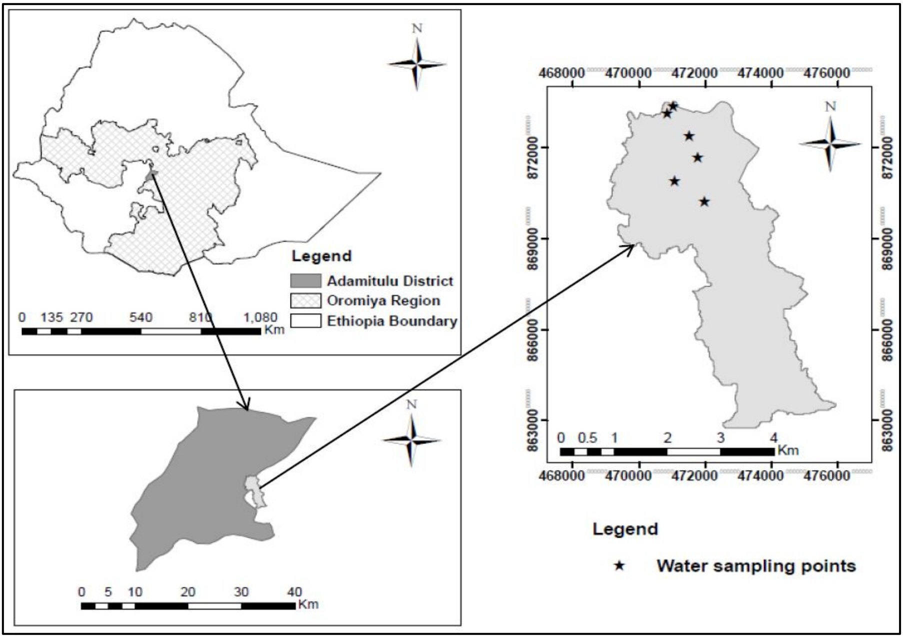

Figure 1: Location map and sampling points

2.1.2. Climate and land use

Figure 2 shows the metrological data of the study area (1997 - 2017) which was obtained from a weather station. The average relative humidity is 46.5% during the dry season and 75.5% during the wet season. The average minimum temperature is 19.2 ^{0}C and the average maximum temperature is 27.5 ^{0}C. A major rainfall event in the area occurs between June to September and a minor rainfall event occurs between March and May. The main rainy season accounts for 70-80% of the total annual rainfall that the area received. The mean annual rainfall in the area ranges from 600 mm to 850 mm and the rainfall pattern is erratic and unreliable. However, the annual average potential evapotranspiration is approximately 1200 mm, which signifies the importance of irrigation to filling the gap.

Geology of the area is marked by a thick cover of volcano-lacustrine and fluvial-lacustrine deposits/sediments (Giday et al. 1990; Halcrow, 2008). They are laid down in a very wide lake which in the past occupied most of the rift floor. Giday et al., 1990 reported that the four lakes such as Ziway, Langano, Abiyata, and Shala were believed to be the remnants of that ancient lacustrine basin. The oldest volcanic rocks are also found in the western and eastern escarpments. The soil type dominantly is Solonchacks developed from evaporates and salt-rich parent materials (Alemayehu et al. 2016).The property of the soil ranges from slightly alkaline to strongly alkaline and is dominantly sandy loam in texture. Topographically the area is characterized by plain to undulated hills located adjacent to the escarpment of the central part of the Ethiopian mountain channels.

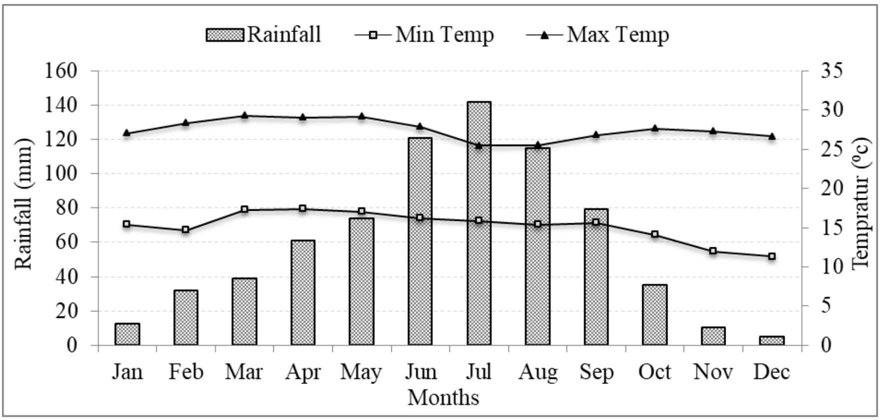

Figure 2: Mean monthly rainfall and temperature of the study area (1997 - 2017)

The major land-use types practiced in the area are related to cultivation and grazing. The cultivable land is concentrated in the flat area while grazing land is located in the hilly area and lakeshores. The cropping patterns are dominated by horticultural crops during the irrigation seasons and cereal crops during rainy seasons. The major cash crops grown in the area are: tomato, cabbage, onion, and beans whereas maize, teff, and wheat are considered main food crops. The most dominant types of livestock found in the area are cattle and goats with limited numbers per household. The natural vegetation occupies the nearby lake and river banks and is composed of bushes and acacia species.

2.2. Site selection and sampling techniques

2.2.1. Site selection

The study area is selected based on food insecurity problems that prevalently occurred in the area due to unreliable climatic conditions. Besides that, the area is well known for the shortage of rainfall but is suitable for irrigated agriculture using surface and/or groundwater sources. Agriculture is the most dominant form of economic activity in the area to support the livelihood of the inhabitants. Moreover, the farming system is traditional and highly dependent on rain as a source of water for agricultural activities. However, recently the government and non-governmental organizations have given due attention to improving this situation in the area through facilitating small scale irrigation practices. There are also different private companies developing irrigation facilities to produce mainly vegetables and flowers. These activities may put pressure on the utilization of available water sources in the area. Hence, evaluating the quality of irrigation water found near to farmlands is critical to take action in time with respect to its limitations.

2.2.2. Sampling techniques

An attempt was made to find out the characteristic features of the boreholes and abstraction points along the Bulibula River through preliminary surveys. The survey was conducted using an informal discussion with extension workers and model farmers who were actively engaged in irrigation practices. More emphasis was given to irrigation practices and the type of water sources they used to do such practices in the village. The data indicated that farmers practiced irrigation in the dry season to cultivate vegetables by using surface and groundwater sources. In most cases, they used boreholes around farm fields for irrigation but those nearby home yards for domestic consumption. The water level data collected during survey time also indicated that boreholes used for irrigation showed more fluctuation compared to those used for domestic consumption. Hence, four boreholes that were frequently used for supplying water to the irrigated fields were selected for sampling purposes. Two abstraction points that frequently used for irrigation along the Bulibula River were also selected for collection of surface water samples. The analyzed quality parameters and sampling frequency were chosen based on the objectives of the study. The depth of boreholes varied from 10 m to 12 m. The diameter for all monitoring boreholes was 1 m on average. The water level in boreholes varied from 0.25 m in the dry season to 2.25 m in the rainy season.

2.3. Sample collection and laboratory analysis

2.3.1. Sample collection

The sampling was done at the beginning of February and at the end of May for two consecutive years (2016 - 2017). These sampling periods were selected based on the purpose of the research that aimed to see seasonal changes effect on the quality of water used for irrigation in the area. Besides that, it was also hypothesized that variation in water sources and sampling time could have effects on water quality that in turn could influence its suitability for irrigated agriculture. Consequently, the water samples were collected from two abstraction points along the Bulbulla River: an outflow from Lake Ziway and the one that feeds Lake Abiyata. Samples from four representative boreholes that farmers used for irrigating their crops were also collected after ten minutes of pumping to maintain the representativeness of the water that comes from the aquifer. Six water samples at a time and a total of twenty-four samples were collected using one-liter capacity plastic bottles for laboratory analysis. The global positioning system (GPS) was used to record the geographic location (latitude and longitude) and elevation with respect to mean sea level (MSL) of each sampling point. The geographical position and other details of sampling locations are presented in Figure 1.

The bottles used for the sample collection were washed carefully with detergent to maintain the quality of the data. The bottles were filled to the top, sealed and labeled with a unique code number which was maintained throughout the laboratory analysis period to enhance the accuracy of results. The collected samples were stored in iceboxes after filtration and brought to the laboratory within 24 hours and then stored in a freezer at 4 °C for further chemical analysis. The analysis was carried out at Arba Minch University Water Quality Laboratory Center according to the standards set for irrigation water quality (Ayers and Westcot, 1985: FAO, 1989). The laboratory analysis determined the contents of different quality parameters; pH, EC, $CaCO_3$, TSS, CO_3^{2-}, HCO_3^-, NO_3^-, PO_4^{3-}, Cl^-, K^+, Ca^{2+}, Mg^{2+}, Na^+ and B. Secondary quality indices such as SAR, SSP, KR, RSC, TDS, MAR, and PI were also determined from analyzed parameters using standard equations.

2.3.2. Laboratory analysis

Analyses of physicochemical properties of the water samples were done using standard laboratory procedures as suggested by Ayers and Westcot (1985). The electrical conductivity (EC) was determined by LF-191 WTW conductivity meter after calibrating with standard potassium chloride solution as suggested by Greenberg et al. (1992). The pH was determined using Jenway-3510 pH-meter after calibrating the apparatus with pH-meter standard solution as suggested by Greenberg et al. (1992). Soluble cations such as Na^+ and K^+ were determined by using Jenway PFP-7 flame photometer after proper calibration with sodium and potassium standard solutions from NaCl and KCl as suggested by RTI (1991). Soluble Ca^{2+} and Mg^{2+} were analyzed directly by the atomic absorption spectrophotometer following the procedures suggested by APHA (1998). Calcium carbonate ($CaCO_3$), carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions were measured by acidimetric titration method while chlorides (Cl^-) was determined by the argentometric titration method against silver nitrate standard solution with potassium chromate indicator by using the procedures suggested by Greenberg et al. (1992). Similarly, phosphate (PO_4^{3-}), nitrate (NO_3^-) and boron (B) were determined by using UV-VIS spectrophotometer after proper calibration with appropriate standard solutions as described by AOAC (1990). The water quality parameters were tested and their respective recommended values for agricultural uses were described in Table 1.

Table 1.The acceptable ranges of water quality parameters recommended for agricultural uses

Parameters	Symbol	Unit	Acceptable range	Source
Alkalinity/Basicity	pH	0-14	6.5-8.4	Ayers & Westcot (1985)
Electrical conductivity	EC	dS/m	0-3	
Calcium	Ca^{2+}	mg/l	0-400	
Magnesium	$Mg2^{+}$	mg/l	0-60	
Sodium	Na^{+}	mg/l	0-1000	
Potassium	K^{+}	mg/l	0-2	
Carbonate	CO_3^{2-}	mg/l	0-3	
Bicarbonate	HCO_3^{-}	mg/l	0-519	
Chloride	Cl^{-}	mg/l	0-355	
Boron	B	mg/l	0-3	
Nitrate-Nitrogen	NO_3^{-}	mg/l	0-10	
Phosphate-Phosphorous	PO_4^{3-}	mg/l	0-2	
Total suspended solids	TSS	mg/l	0-100	

Parameters	Symbol	Unit	Acceptable range	Source
Total dissolved solids	TDS	mg/l	0-2000	
Sodium adsorption ratio	SAR	meq/l	0-15	
Calcium carbonate	$CaCO_3$	mg/l	0-300	Sawyer & McCarty (1967)
Residual sodium bicarbonate	RSBC	meq/l	<1.25	Gupta & Gupta (1987)
Residual sodium carbonate	RSC	meq/l	<2.5	Raghunath (1987)
Kelly ratio	KR	meq/l	<1	Kelly, 1963
Permeability index	PI	%	>65	Doneen (1964)
Magnesium adsorption ratio	MAR	%	<50	Raghunath (1987)
Soluble sodium percentage	SSP	%	<60	Todd, 1980

The Sodium adsorption ratio (SAR) is a widely accepted parameter for characterizing the soil solution concerning its likely influence on exchangeable sodium. The SAR was estimated by using Equation 1 as suggested by Ayers and Westcot (1985). The concentrations of all ions in this equation are expressed in milliequivalents per liter.

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \qquad (1)$$

A total dissolved solid (TDS) was used to predict the concentration of ions in the soil. The TDS was estimated by using Equation 2 as suggested by Landon (1991). All ionic concentrations in this equation were expressed in milligrams per liter.

$$TDS\ (mg/L) = EC\ (dS/m) * K \qquad (2)$$

Where, K = 640 in most cases (for EC: 0.5 -5 dS/m) or K = 735 for mixed waters or K = 800 for EC > 5 dS/m

The Residual sodium carbonate (RSC) that existed in irrigation water was estimated by using Equation 3 as suggested by Raghunath (1987). The concentrations of all ions in this relation were expressed in milliequivalents per liter.

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \qquad (3)$$

The Residual sodium bicarbonate (RSBC) was estimated by using Equation 4 as suggested by Gupta and Gupta (1987). The concentrations of all ions in this relation were expressed in milliequivalents per liter.

$$RSBC = HCO_3 - Ca \qquad (4)$$

The Magnesium adsorption ratio (MAR) represents magnesium hazard in irrigation water. The high value of MAR in irrigation water might cause calcium-induced nutritional deficiency. It was estimated using Equation 5 as described by Raghunath (1987). Ionic concentrations in Equation 5 were expressed in milliequivalents per liter.

$$MR = (Mg * 100)/(Ca + Mg) \tag{5}$$

The Soluble sodium percentage (SSP) was used to figure out how the concentration of sodium ion in irrigation water influenced soil structure. The SSP was estimated by using Equation 6 as suggested by Todd (1980). The concentrations of all ions in this equation were expressed in milligrams per liter.

$$SSP = \left(\frac{Na + K}{Ca + Mg + Na + K}\right) * 100 \tag{6}$$

The Permeability Index (PI) was used to estimate how the permeability of the soil was affected by sodium, calcium, magnesium, and bicarbonate contents of irrigation water. The PI of irrigation water was estimated by using Equation 7 as suggested by Doneen (1962). All ionic concentrations in Equation 7 were expressed in milliequivalents per liter.

$$PI = \left(\frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na}\right) \tag{7}$$

Kelly's ratio (KR) is an equation developed for determining sodium related problems in irrigation water. The KR was estimated by using Equation 8 as described by Kelly (1963). And all ionic concentrations in Equation 8 are also expressed in milliequivalents per liter.

$$KR = \frac{Na}{Ca + Mg} \tag{8}$$

2.3. Statistical analysis

Generalized linear model procedure in a statistical package for the social science (SPSS) version 16 application was used in the analysis of the data. A general linear model of two ways analysis of variance (ANOVA) was used to determine whether differences existed among mean of water quality parameters across the location and irrigation water sources. The mean of each parameter was compared to the water sources and sampling points using post-hoc comparison tests. It was carried out to find exactly where the difference lies between the mean of each quality parameter across all points and water sources.

3. RESULTS AND DISCUSSION

This study attempted to evaluate the surface and groundwater quality for irrigated agriculture in the study area. The water samples from both sources were collected at the beginning of February (before planting) and at the end of May (after harvesting) for two consecutive years. The results of the laboratory analysis of water samples for different parameters were recorded and displayed using tables and figures. The mean value of all quality parameters obtained from the analysis of variance at all points and sources were presented in Table 2 and 3. Some of the other quality indicators that were used to evaluate the suitability of water sources for irrigation purposes were also presented in Table 4. The graphical presentation that compares water quality parameters with respect to sampling time and water sources in the area is shown in Figures 3 and 4.

3.1. Variability of irrigation water quality across the location

The variability of different water quality parameters across the sampling locations is shown in Table 2. As in Table 2, the majority of water quality parameters did not vary considerably with sampling locations. About 35.7 ($P<0.05$) of the studied quality parameters showed a significant difference across sampling points (Table 2). The remaining 64.3% of the parameters did not show such variations at all sampling points. This may suggest that the irrigation water that farmers used in the area was different in terms of quality across spatial distributions. This variation might be attributed to the vegetable crops dominated farming system that existed in the area. Such type of farming practices might favor loss of nutrients from farmlands through irrigation water due to intensive use of chemicals. This situation, in turn, could influence the quality of surface and/or groundwater sources. Water quality variation might also result from chemical compositions of earth materials found in the area. These might be the possible reasons for the variability of irrigation water quality that observed in the area.

The standards for different water quality parameters for irrigated agriculture are given in Table 1. As shown in Table 2, the pH and EC values in the area ranged from 7.83 to 8.23 and 0.48 dS/m to 2.73 dS/m, respectively. The value of pH did not show variation across sampling points while the EC value showed strong variation across sampling points. In some points, the pH values approaching the upper boundary suggested continuous use of water for irrigation. This might have effect on soil quality in the area. However, the average pH value (8.10) and EC value (1.30dS/m) remained below the critical limits and this was recommended for irrigated agriculture (Table 1). The water samples were found to be within the safe limits for irrigation concerning these parameters. This finding was in agreement with the previous report by Abay et al. (2016) in the same area.

Table 2. Variation of irrigation water quality across sampling points in the area

Parameters	Surface water source		Groundwater source				Average	S.E of mean	Sig.	LOS
	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6				
PH	8.20[a]	7.98[a]	8.10[a]	8.23[a]	7.83[a]	7.93[a]	8.06	0.27	0.90	NS
EC	0.52[a]	0.48[b]	2.03[a]	2.73[ab]	1.63[a]	1.91[a]	1.29	0.17	0.00	*
Na^{+}	255.85[a]	262.80[a]	398.75[a]	564.00[a]	388.75[a]	445.75[a]	354.32	86.46	0.10	NS
Ca^{2+}	39.30[a]	38.08[a]	65.55[a]	45.05[a]	60.55[a]	69.13[a]	49.38	10.98	0.11	NS
CO_3^{2-}	32.75[a]	27.50[a]	44.25[a]	52.75[a]	79.00[a]	81.00[a]	47.19	19.88	0.17	NS
HCO_3^{-}	314.50[a]	280.25[b]	932.50[a]	1028.80[a]	960.00[a]	910.75[a]	627.69	156.39	0.03	*
K^{+}	189.00[a]	228.50[a]	370.50[a]	367.75[a]	302.75[a]	311.00[a]	273.38	61.25	0.24	NS
Mg^{2+}	26.50[a]	27.35[b]	49.50[a]	50.63[a]	57.60[a]	58.65[a]	40.51	7.69	0.01	*
Cl^{-}	35.75[a]	37.25[b]	69.75[a]	216.75[a]	111.25[a]	145.75[a]	86.19	23.86	0.02	*
NO_3^{-}	96.10[a]	126.88[a]	38.80[a]	26.63[a]	44.18[a]	32.83[a]	73.55	26.53	0.15	NS
PO_4^{3-}	0.62[a]	0.79[a]	1.12[a]	0.99[a]	1.09[a]	0.87[a]	0.87	0.42	0.93	NS
B	0.05[a]	0.08[a]	0.52[a]	0.75[a]	0.28[a]	0.14[a]	0.24	0.21	0.40	NS
$CaCO_3$	136.75[a]	124.00[b]	311.25[ab]	262.50[a]	297.50[a]	310.00[a]	240.33	31.92	0.00	*
TSS	221.00[a]	165.00[a]	276.00[a]	399.75[a]	196.00[a]	182.50[a]	240.04	66.63	0.22	NS

Note: * Significant at $p<0.05$, NS; None significant, WS-1toWS-6; Water sample codes, S.E; Standard error, LOS; Level of significance.

As shown in Table 2, the same letters in the same row were refers to the existence of insignificant difference among the means of quality parameters across the location. The concentrations of Ca^{2+} and Mg^{2+} in irrigation water varied from 38.08 mg/l to 69.13 mg/l and 26.50 to 58.65 mg/l, respectively (Table 2). The value of Ca^{2+} did not show variation across sampling points while Mg^{2+} showed noticeable variations. This might be attributed to the way of farm management practices that farmers practiced in their respective fields. The highest value for both parameters observed at similar points suggested that the concentration gradient of these ions showed similar trends in the area. However, the average Ca^{2+} value (49.40 mg/l) and Mg^{2+} value (40.50 mg/l) remained below the critical limits recommended for irrigated agriculture (Table 1). There was no restriction in the level of these parameters used for water irrigation. The concentration of K^+ across sampling points ranged from 189.00 mg/l to 370.50 mg/l (Table 2). Unlike others, its concentration was very high in all sampling points during the whole study periods. This could be attributed to the chemical composition of underlying rocks found in the area. Halcrow (2008) and Abay et al. (2016) also reported similar findings concerning these parameters.

The concentration of Na^+ in irrigation water in the area ranged from 255.85 mg/l to 564.00 mg/l (Table 2). Its concentration in all points remained by far higher than Ca^{2+} and Mg^{2+} in the area. This suggests that irrigating farmlands might increase Na^+ concentration in the soils. This situation could bring about toxicity problems on growing crops besides physical deterioration of soil quality. According to the standards indicated in Table 1, the value of Na^+ fell within the permissible range. The other common toxic ions and elements found in irrigation water were chloride (Cl^-) and born (B). The concentrations of these parameters across sampling points varied from 35.75 mg/l to 216.75 mg/l and 0.05 mg/l to 0.72 mg/l, respectively (Table 2). The value of B did not show significant variation across sampling points while Cl^- showed noticeable variation. However, their concentrations in all sampling points were within the acceptable limit suggested for irrigation (Table 1).

The values of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) in all locations varied from 27.50 mg/l to 81.00 mg/l and 280.25 to 1028.80 mg/l, respectively (Table 2). The value of CO_3^{2-} did not show variation across sampling points while HCO_3^-showed significant variation. The concentrations of both CO_3^{2-} and HCO_3^- across the location remained above the limit (Table 1). This data suggested that the use of water for agricultural purpose might cause negative impacts on soil quality. Since, high concentration of CO_3^{2-} and HCO_3^- in irrigation water will tend to precipitate calcium and magnesium ions. This situation, in turn, will increase the sodium hazard of the soil water. The abundance of these parameters in the area might be attributed to geologic materials of the aquifer from which the water is drawn. As shown in Table 2, the value of nitrate (NO_3^-) and phosphate (PO_4^{3-}) in the area ranged from 26.63 to 126.88 mg/l and 0.62 mg/l to 1.12 mg/l, respectively. Both parameters did not show any meaningful variation across sampling points. However, high concentration on both cases was observed during the investigation period. This might be attributed to the dominance of vegetable production in the area. Because such type of farming system in most cases favored intensive use of agricultural inputs which in turn could increase their concentration in water bodies. The concentrations of NO_3^- in all points remained above the limit (10 mg/l) while PO_4^{3-}concentrations were found to fall within the range (Table 1). These findings agreed with the previous findings reported by Halcrow (2008) and Abay et al. (2016) in the same area.

The value of total hardness as $CaCO_3$ in the area during the investigation period ranged from 124 mg/l to 310 mg/l (Table 2). Like the previous one, this parameter was also showed a higher value in all sampling points. Sawyer and McCarty (1967) reported that $CaCO_3$ with <75 mg/l values was considered to be soft, 75 to 150 mg/l moderate, 150 to 300 mg/l hard and very hard when it exceeded 300 mg/l. As indicated in Table 2, the average value of $CaCO_3$ (240 mg/l) remained below the critical limit (300 mg/l) and thus the irrigation water was taken as hard. However, excessive hardness may cause foliar deposits of calcium or magnesium carbonate under overhead irrigation. The value of TSS across the locations varied from 165 mg/l to 400 mg/l (Table 2). Similarly, the concentration of TSS in all sampling points remained above the critical limit (100 mg/l), which suggested for irrigated agriculture (Table 1). In both cases, the use of the water for irrigation might affect the efficiency of emitters in the drip irrigation system due to their clogging effects. Hence, monitoring the quality of irrigation water across the sources and proper irrigation management was found to be critical to sustain agricultural productivity in the area.

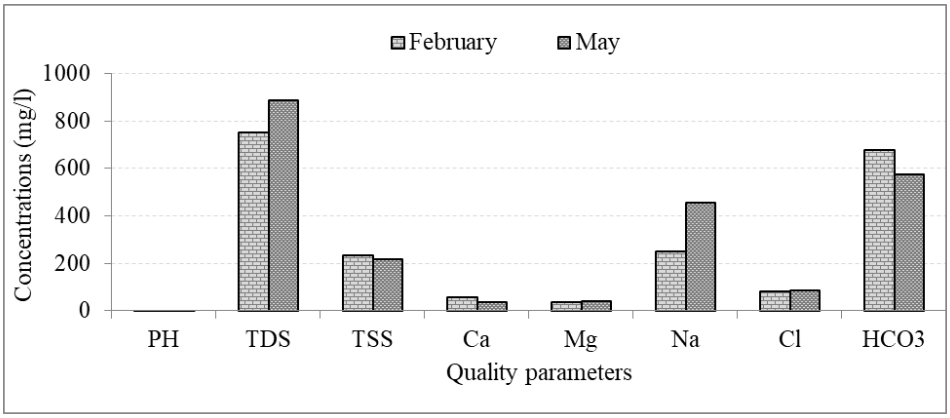

Figure 3: Mean seasonal variation of irrigation water quality parameters in the area

Figure 3 showed the comparison of water samples collected at the beginning of February and at the end of May in 2016 and 2017. In Figure 3, almost all of the displayed quality parameters showed variation across sampling time. This implies that seasonal variations could have remarkable impacts on the quality of irrigation water in the area. Most of the time seasonal variations were indicated by higher total suspended solids (TSS) and lower salinity in the wet season. This could be attributed to the sediment load of runoff and dilution effects of rainfall that existed in the wet season. However, total dissolved solids (TDS) and total suspended solids (TSS) showed different trend from this argument across the season in the area. This might be probably due to poor farm management practices. In most cases, poor farming practices could bring leachable salts from the surrounding farming system to water bodies. The leaching process, in turn, could increase the concentration of such constituents in the nearby water sources. This might be the reason why the concentration of those parameters showed such trends at the end of the dry season in the area. And also the declining trend for some parameters such as calcium at the end of the growing season might be attributed to dilution effects of rainfall in addition to farming practices.

Therefore, use of improved farm management practice is very important to maintain the quality of irrigation water in the area.

3.2. Variability of water quality across water sources

The variation of different irrigation water quality parameters across irrigation water sources was presented in Table 3 in which 64.30% of the quality parameters showed a significant difference at $P<0.05$ across water sources. The remaining 35.70% of the parameters did not show such variations across the sources. This implied that variation in irrigation water sources had strong influence on the quality of irrigation water that farmers used in the area. Because the majority of water quality parameters showed noticeable variation at both water sources. Moreover, about 93% of the quality parameters showed higher values in groundwater samples compared to surface water during the investigation periods. This suggested that the quality of groundwater could be an issue in the area and might need due attention during planning of irrigation projects.

In Table 3, the pH and EC values across water sources ranged from 8.02 to 8.09 and 0.50 dS/m to 2.07 dS/m, respectively. The highest value for both parameters was observed in groundwater samples. This might be attributed to the contaminants of soil constituents that dissolved with percolating water and drained to groundwater sources. Such processes, in turn, could increase the concentration of easily leachable parameters in groundwater sources. This might suggest that the use of groundwater for irrigation would more likely influence soil quality compared to surface water. However, the values of both parameters during the investigation period remained below the critical limits recommended for irrigated agriculture (Table 1). In this regard, the values of both parameters for the investigated water sources were found within the standard limits (Table 3). Hence, appropriate use of water for irrigation might not have as such adverse effect on cultivable crops. This finding was in agreement with the previous findings reported by Halcrow (2008) and Abay et al. (2016).

Table 3. Variation of water quality across water source in the area

Parameters	SW	GW	Average	S.E of mean	Sig.	LOS
pH	8.02	8.09	8.05	0.11	0.78	NS
EC	0.50	2.07	1.28	0.17	0.00	*
Na^{+}	259.33	449.31	354.32	37.61	0.02	*
Ca^{2+}	38.69	60.07	49.38	4.51	0.05	*
CO_3^{2-}	25.13	44.25	34.69	9.74	0.44	NS
HCO_3^{-}	297.38	958.00	627.69	83.44	0.00	*
K^{+}	208.75	338.00	273.38	26.02	0.03	*
Mg^{2+}	26.93	54.10	40.51	3.72	0.00	*
Cl^{-}	36.50	135.88	86.19	16.36	0.01	*
NO_3^{-}	111.49	35.61	73.55	13.07	0.01	*
PO_4^{3-}	0.71	0.97	0.84	0.14	0.46	NS
B	0.07	0.43	0.25	0.10	0.17	NS
$CaCO_3$	130.38	295.31	212.84	20.16	0.00	*
TSS	193.00	263.56	228.28	27.17	0.28	NS

Note: * Significant at $p<0.05$, NS; None significant, SW; Surface water, GW; Groundwater, S.E; Standard error, LOS; Level of significance.

The concentrations of Ca^{2+} and Mg^{2+} in both irrigation water sources varied from 38.69 mg/l to 60.07 mg/l and 26.93 to 54.10 mg/l, respectively (Table 3). The highest value for both of these parameters was also observed in groundwater samples. This implied that irrigating the farms with groundwater in the area might increase salt contents in the soil which in turn could influence soil quality. However, the values of both parameters across water sources remained below critical limits recommended for irrigated agriculture (Table 1). The concentration of K^{+} in irrigation water across the water source ranged from 208.75 mg/l to 338.00 mg/l (Table 3). Similarly, its highest value during the study period was also observed in groundwater samples. However, the concentration of this parameter in both water sources remained very high compared to its critical limit (Table 1). This might be due to the nature of rocks that were found in the area. Similar findings were also reported earlier by Halcrow (2008) and Abay et al. (2016).

As indicated in Table 3, Na^+ values in irrigation water across the sources ranged from 259.33 mg/l to 449.31 mg/l. The highest value for this parameter was also observed in groundwater samples. Moreover, its concentration in both irrigation water sources remained by far higher than Ca^{2+} and Mg^{2+} throughout the study period. This suggested that irrigating farmlands with both water sources could increase Na^+ contents in the soil. As a result, the yield of irrigated crops maybe reduced due to its toxicity effects. Besides, continuous use of groundwater for irrigating farmlands might cause physical deterioration of soil quality in the area. As the standards indicated in Table 1, the values of Na^+ across water sources were found within the acceptable range recommended for agricultural uses. The other common toxic ions and elements found in irrigation water were chloride (Cl^-) and Born (B). Their concentration in both water sources varied from 36.50 mg/l to 135.88 mg/l and 0.07 mg/l to 0.43 mg/l, respectively (Table 3). The highest value of these parameters was also observed in groundwater samples. However, the values of both parameters in studied water sources were found within the acceptable limit suggested for irrigated agriculture (Table 1). This finding was in agreement with the previous finding reported by Abay et al. (2016) in the area.

The value of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) across the water sources varied from 25.13 mg/l to 44.25 mg/l and 297.38 mg/l to 958.00 mg/l, respectively (Table 3). The highest value for these parameters was also observed in groundwater samples during the investigation period. This suggested that irrigating the farm fields with groundwater sources might cause deterioration of soil quality. Since high concentrations of these parameters in irrigation water could result in precipitation of Ca^{2+} and Mg^{2+} which in turn could reduce their content in soil complex. Subsequently, such processes might cause the disintegration of soil aggregates in irrigated fields. Moreover, their concentrations across water sources remained very high during the whole study periods. This suggested that the continuous use of water for irrigation might affect soil quality. Halcrow (2008) also reported very high values for these parameters earlier in this area.

In Table 3, it was shown that Nitrate (NO_3^-) and phosphate (PO_4^{3-}) values across water sources ranged from 35.61 to 119.49 mg/l and 0.71 to 0.97 mg/l, respectively. . The highest value for NO_3^- was observed in surface water and in groundwater samples for PO_4^{3-}.. This might be attributed to poor agricultural practices that caused the loss of leachable nutrients from the farming system. Ultimately the nutrients leached into nearby water bodies or rivers with irrigation/rainwater. This could be the possible reason for the occurrence of a high concentration of NO_3^-in surface water compared to groundwater. Besides, a high concentration of both parameters across water sources might be attributed to poor fertilizer management practices that existed in the area. The concentration of NO_3^-in both water sources remained above the limit while PO_4^{3-} concentration was found within the acceptable range (Table 1).This suggested that the use of improved irrigation management practices was essential to reduce the loss of such nutrients from agricultural fields. This finding agreed with previous findings reported by Halcrow (2008) and Abay et al. (2016).

The values of $CaCO_3$ and TSS in the study area are ranged from 130.4 mg/l to 295.3 mg/l and 193.0 to 263.6 mg/l, respectively (Table 3). The highest value of these parameters was also observed in groundwater samples during the investigation periods. However, both of these parameters showed high values across water sources. This might be associated with farmers' traditional way of land management practices. Moreover, the average $CaCO_3$ value (212.8 mg/l) and TSS value (228.3 mg/l) during the study period remained higher than the standards recommended for irrigation uses (Table 1). This suggested that the use of water for irrigation might affect the function of emitters in drip irrigation systems. Hence, monitoring each part of the drip system was found to be very important to improve its efficiency which in turn could enhance agricultural productivity.

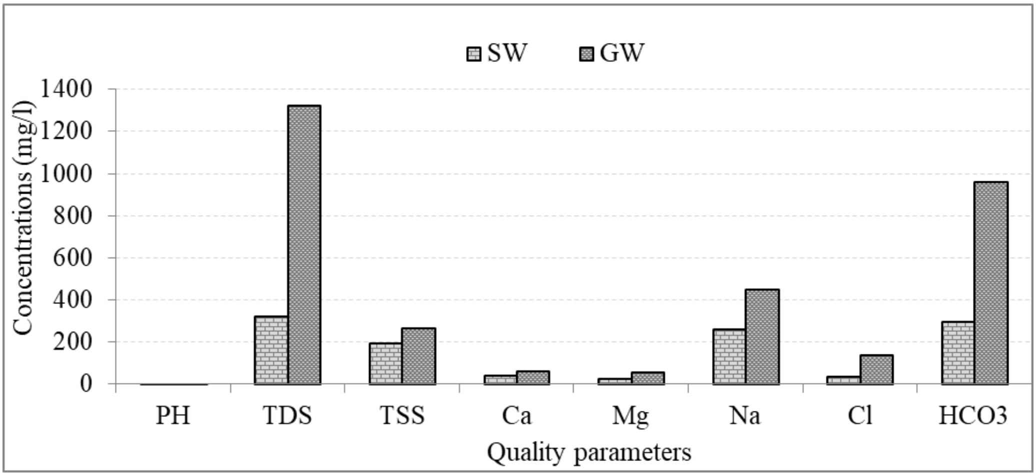

Figure 4. The comparison of mean surface and groundwater quality in the area

The comparison of water quality parameters across the water source was presented in Figure 4 wherein almost all of the studied parameters related to water quality showed higher values in groundwater samples. This suggested that the variation in water sources could have noticeable impacts on the quality of water that was supposed to be used for irrigation in the area. However, the pH value of the assessed water samples did not show as such a remarkable change across the water sources. As clearly observed in Figure 4, the remaining quality parameters had shown a consistently increasing trend in groundwater samples. This could possibly be attributed to the chemical composition of the geological materials through which it passed in the soil system. Besides, the expansion of vegetable and flower production in the area might influence the concentration of such constituents in groundwater samples. Vegetable dominating farming system, in most cases, caused excessive leaching of salts out of the system. Subsequently, the salts that lost from the farming system could easily leach into the groundwater sources through the percolation process. These processes might be accountable for the presence of a high concentration of those parameters in groundwater samples compared to surface water. Hence, paying attention to the quality of groundwater was very important as long as it was to be used for irrigation in the area.

3.3. Suitability of water quality for irrigation

The use of poor quality irrigation water could create four types of problems: salinity, sodocity (permeability), toxicity, and miscellaneous effects (Brady and Weil, 2002; Hillel, 2004). All these points were considered in this evaluation process that aimed to check out its suitability for irrigation uses. The secondary quality indicators that were used to evaluate the suitability of water quality for irrigated agriculture in the area were presented in Table 4. The value of SAR was estimated using equation 1 and its value ranged from 7.43 meq/l to 13.45 meq/l (Table 4). This implied that the observed values were relatively high and it might be due to lower values of Ca^{2+} and Mg^{2+} compared to Na^{+}. The highest value of SAR was observed in groundwater samples compared to surface water samples. This suggested that groundwater was more alkaline than surface water in the area. The water having SAR values less than 15 meq/l was considered safe for irrigation uses (Table 1).

In this regard, the average value of SAR at both water sources was found within the acceptable limit and could be suitable for irrigation (Table 4). However, sodocity problem generally increased with increasing salinity and decreased with either decreasing salinity or increasing sodium content relative to calcium and magnesium. Therefore, the two factors, EC/TDS and SAR, had to be considered together for a proper evaluation of the ultimate effect on soil properties. The combining effect of SAR and TDS values indicated that the use of both water sources for irrigation could moderately affect the infiltration rate of the soil in the area. Hence, paying attention to management practices such as periodic cultivation, deep tillage, use of organic residues, and on-farm water managements were considered very important to reduce its adverse effects. Higher SAR values for groundwater sources were also reported by Halcrow (2008), Abay et al. (2016) and Hadera (2018) in the same area.

Table 4. Some of the calculated water quality parameters in the area

Parameters	Surface water		Groundwater				ASW	AGW	TA
	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6			
SAR	7.68	7.43	9.37	13.45	9.10	10.17	7.56	10.52	9.04
SSP	79.28	80.51	78.38	83.99	75.91	76.63	79.9	78.73	79.31
KR	2.67	2.73	2.34	3.79	2.16	2.32	2.70	2.65	2.68
RSC	2.07	0.99	8.36	10.82	10.54	9.29	1.53	9.75	5.64
RSBC	3.19	2.69	12.01	14.61	12.71	11.47	2.94	12.70	7.82
TDS	331.36	306.4	1295.40	1742.9	1041.60	1222.20	318.88	1325.53	822.20
MAR	80.69	79.19	94.29	95.40	93.21	94.10	79.94	94.25	87.10
PI	91.37	92.24	90.46	97.16	87.47	88.56	91.81	90.91	91.36

Note: ASW; Average value of surface water, AGW; Average value of groundwater, TA; Total average value, WS-1-WS-6; Sample codes.

The values of RSC and RSBC were estimated using equations 3 and 4, respectively. Their values across sampling points ranged from 0.99 meq/l to10.82 meq/l and 2.29 meq/l to 14.61 meq/l, respectively (Table 4). In both cases, the highest value was observed in groundwater samples compared to surface water samples. Hence, paying attention to groundwater quality in the area was critical during the planning of irrigation practices. Water having a high concentration of residual carbonates and bicarbonates could increase Na^{+} hazards in irrigated fields. Since, these parameters in most cases caused precipitation of Ca^{2+} and Mg^{2+} in soil solution. The estimated average RSC values (ASW=1.53 meq/l; AGW=9.75 meq/l) and RSBC values (ASW=2.97 meq/l; AGW=12.70 meq/l) under both cases remained beyond the critical limit (Table 1). Therefore, it is important to use improved management practices while using the water for irrigation to maintain soil productivity. The values of TDS were estimated using equation 2 and it ranged from 306.40 mg/l to1742.90 mg/l (Table 4). Like others, its highest value was observed in groundwater samples. This implied that groundwater quality should be an issue in the area and needed due attention. However, under both cases, its value remained within the permissible limit and was believed to be suitable for irrigation. A similar result was also reported by Halcrow (2008) earlier in this area considering these parameters.

The SSP and KR were also widely used parameters for evaluating the suitability of water quality for irrigation uses. Excess sodium ion concentration in irrigation water could produce undesirable effects on soil and crops. The SSP and KR values were estimated using equations 6 and 8, respectively. Their values across sampling locations ranged from 75.91/% to183.99% and 2.16 meq/l to 3.79 meq/l, respectively (Table 4). The values of SSP below 60% (Reddy, 2013), KR <1 (Kelly, 1963) were considered good and safe for irrigation uses. However, both surface and groundwater samples values in the area had shown above this limit (Table 4). This also suggested irrigating the fields regularly with the water might cause sodium related problems.

Likewise, the MAR and PI values were estimated using equations 5 and 7 and their values across sampling points ranged from 79.19% to 95.40% and 87.47% to 97.16%, respectively (Table 4). In both cases, the highest values were observed in groundwater samples. Both of these parameters could be used to evaluate long term effects of irrigation water quality on soil property. The values of MAR <50% and PI >65% were considered as good and safe for irrigation uses (Table 1). However, the average value of MAR under both cases remained beyond this critical limit during the entire study periods (Table 4). This suggested that the continuous use of both water sources for irrigation purposes might cause calcium-induced fertility problems in the area. But the PI values were found within the acceptable limits for irrigated agriculture (Table 4).

4. CONCLUSIONS AND RECOMMENDATIONS

The quality of irrigation water available to farmers and other irrigators had a considerable impact on crop yield and soil physical conditions. This study, therefore, was conducted in the area to evaluate the suitability of surface and groundwater quality for irrigation purposes. Accordingly, the results revealed that about 64.3% of the parameters showed remarkable variation across water sources while 35.7% showed such variation across locations at $P<0.05$. Majority of the quality parameters showed higher values in groundwater samples compared to surface water. This suggested that the quality of groundwater should be considered an issue in the area and paying attention to management practices was thus very important to reduce its adverse effects. The EC and SAR values in all locations were found within acceptable limits for irrigation, but their highest value were observed in groundwater samples. However, the combining effect of SAR and EC indicated that the use of both water sources for irrigation could moderately influence the infiltration rate of the soil in the area.

The RSC and RSBC values in groundwater samples remained beyond the permissible limit. This suggested that the use of groundwater for irrigation without considering management options could deteriorate soil structure. The values of SSP and KR had shown higher value during the investigation period and suggested irrigating the fields continuously with the water could increase sodium concentration in soil. The MAR values under both cases were also found above the critical limit, which suggested the use of both sources for irrigation might cause calcium-induced fertility problem. Unlike others, the value of PI was found within the acceptable limit for irrigated agriculture. In general, all crops could be grown effectively with the water sources in the area. However, management practices such as deep tillage, leaching, conjunctive use of both sources, and choice of salt-tolerant crops might help to maximize yield. Almost all studied parameters varied significantly at both water sources. Thus the water should be tested occasionally to assess salt build up in the soil.

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