Vol. 16(11), pp. 1481-1495, November, 2020
DOI: 10.5897/AJAR2020.14707
Article Number: 51051FF65243
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Effect of on-farm water management practices and irrigation water source on soil quality in Central Ethiopia

Demelash Wendemeneh[1*], Mekonen Ayana[2], Partap Singh[1] and Amare Haileslassie[3]

[1]Faculty of Water Resource and Irrigation Engineering, Arba Minch Water Technology Institute, Arba Minch University, Arba Minch, Ethiopia.
[2]Department of Water Resource Engineering, School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia.
[3]International Water Management Institute (IWMI), East Africa and Nile Basin Office, Addis Ababa, Ethiopia.

Received 9 January, 2020; Accepted 18 June, 2020

Soil salinity is the major factor that limits agricultural productivity in arid and semi-arid regions. The use of improved farm management practices in such areas is becoming a highly concerning issue to sustain agricultural productivity. This study, therefore, was conducted to evaluate the effect of on-farm water management practices and irrigation water sources on soil quality. The experiment was conducted on 16 farmer's fields in the area for two consecutive years. Soil and water sampling were done at the beginning and end of each growing season. Both samples were analyzed for selected parameters following standard laboratory procedures. A general linear model of two ways analysis of variance was used to evaluate the variations among treatments. Results indicated that about 64.3% of studied soil properties are showed significant variation at P<5% across treatments. This implies that management practice and sources of irrigation water have an impact on soil productivity. Salinity and alkalinity values showed an increasing trend over time and higher values for both parameters were observed in groundwater irrigated fields. This suggested that irrigation water sources have also pronounced effects on soil quality. The higher value for soil fertility indicators such as organic carbon, nitrogen, and phosphorous was also observed under managed fields. This also suggests management practices positively influenced soil productivity. Therefore, paying attention to management practices and water quality is very important to maintain soil productivity.

Key words: Agriculture, ANOVA, irrigation management, soil salinity, water quality.

INTRODUCTION

Agriculture is the mainstay of the Ethiopian economy contributing almost half of the GDP (43%) and 85% of the total export revenue (CSA, 2018; FAO, 2017). It also supplies a significant proportion of the industrial raw

*Corresponding author. E-mail: demelashwon@gmail.com.

materials and employs more than 85% of the labor force in the country (CSA, 2018). However, agricultural productivity remains meager due to declining of soil fertility, increasing soil salinity, and lack of quality irrigation water. Soil salinity is one of the major land degradation problems in dry regions and highly threatens irrigated agriculture in such environments (Al-Ghobari, 2011; Husien et al., 2017). Moreover, salinity problems have aggravated under poorly managed fields and account for the deterioration of soil productivity. As a consequence, the effective use of irrigation water has become an indispensable component of irrigated agriculture (Edossa et al., 2014; Kefyalew and Kibebew, 2016; Hadera, 2018).

In the past, soil salinity and sodicity problems were developed as a result of the accumulation of salts due to natural causes (Heluf, 1987; Abrol et al., 1988; Michael, 1992; Hillel, 2000, 2004). But, in recent decades, vast areas of salt-affected soils have developed from man-made causes (Seid and Genanew, 2013; Edossa et al., 2014; Mesfin, 2015; Abay et al., 2016; Husien et al., 2017; Qureshi et al., 2018; Hadera, 2018). The main possible factor that triggers salinity problems in irrigated fields is poor irrigation management practices (Tessema et al., 2014; Kefyalew and Kibebew, 2016). Edossa et al. (2014) and Mesfin (2015) noted that the problem of salinity is more serious under poorly managed irrigated fields. Consequently, such situations, in turn, could reduce soil fertility and productivity. Furthermore, the area is highly prone to salinization due to the very low and erratic nature of rainfall the area experienced. As Edossa et al. (2014) and Alemayehu et al. (2016) reported smallholder farmers in the area widely used furrow irrigation methods which could increase the possibility of over flooding. This situation in turn could elevate groundwater levels which favors the movement of more solutes to the soil surface. Besides, the very low and erratic nature of rainfall that is experienced in the area can aggravate the salinization process.

The previous studies have demonstrated the effect of managing irrigated fields on soil productivity in the area. For instance, a study by Hadera (2018) revealed that the use of improved farm management practices considerably reduces the salinity problem in irrigated fields. Kefyalew and Kibebew (2016) investigated the effects of different farm management practices on soil property in the area. The result showed that soil productivity was significantly improved under managed fields compared to unmanaged fields. These studies provided a better understanding of farm managing issues as mitigation strategies for improving soil quality. However, these studies more focused on-farm management practices and did not pay attention to irrigation water quality issues in the area (Seid and Genanaw, 2013; Edossa et al., 2014; Husien et al., 2017). Water quality, in this regard, is a highly concerning issue as long as irrigation is planned to be used for crop production. Al-Ghobari (2011) and Husien et al. (2017) suggested that poor water quality from undesired sources can significantly influence soil productivity. The frequent use of farmland for irrigation purposes without monitoring the quantity of water supplied to the crops leads to a higher probability of making the field saline during cropping seasons (Edossa et al., 2014; Hadera, 2018). This also implies that more studies are required to understand the interactions between management practices and water quality used and their combined effects on soil quality.

Productive use of farmlands requires periodical evaluation of salinity build-up in soils and water quality that supposed to be used for irrigation purposes (Legesse and Ayenew, 2006; Al-Ghobari, 2011; Husien et al., 2017; Qureshi et al., 2018). Because the results will provide reliable information with regard to the effectiveness of management practices implemented to improve soil productivity. Moreover, it also helps the users to design strategies for practicing irrigated agriculture in a sustainable manner. In the present study area, so far some researchers have conducted some researches that are related with on-farm water management practices (Mesfin, 2001; Halcrow, 2008; Seid and Genanaw, 2013; Edossa et al., 2014; Alemayehu et al., 2016; Kefyalew and Kibebew, 2016; Hadera, 2018). However, the conducted researches were given more emphasis on irrigated filed management, but not considered irrigation water source effects on soil quality. The purpose of this study was to test the effects of on-farm water management practices and irrigation water sources on soil quality as measured by the concentration of salinity related soil properties. Therefore, the specific objectives of this study were to (i) evaluate the effect of on-farm water management practices on soil salinity; (ii) evaluate the effect of source of irrigation water on soil salinity; (iii) determine the depth-wise effect of irrigation on soil salinity; and (iv) suggest possible management practices that would help the farmers to avoid soil salinity in their farmlands.

MATERIALS AND METHODS

Descriptions of the study area

Location

The study site is located in Adamitulu district in the South Western Shewa zone of the Oromiya Regional State of Ethiopia (Figure 1). It is geographical location 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 at about 160 km South of Addis Ababa in the vicinity of Lake Ziway.

The study village has occupied with more than 1000 households who are dependent on mixed crop-livestock production systems with irrigation playing an important role. The altitude of the study area is ranged from 1600 to 1900 masl in the tropical semi-arid zone in the middle part of the Ethiopian rift valley system. Since

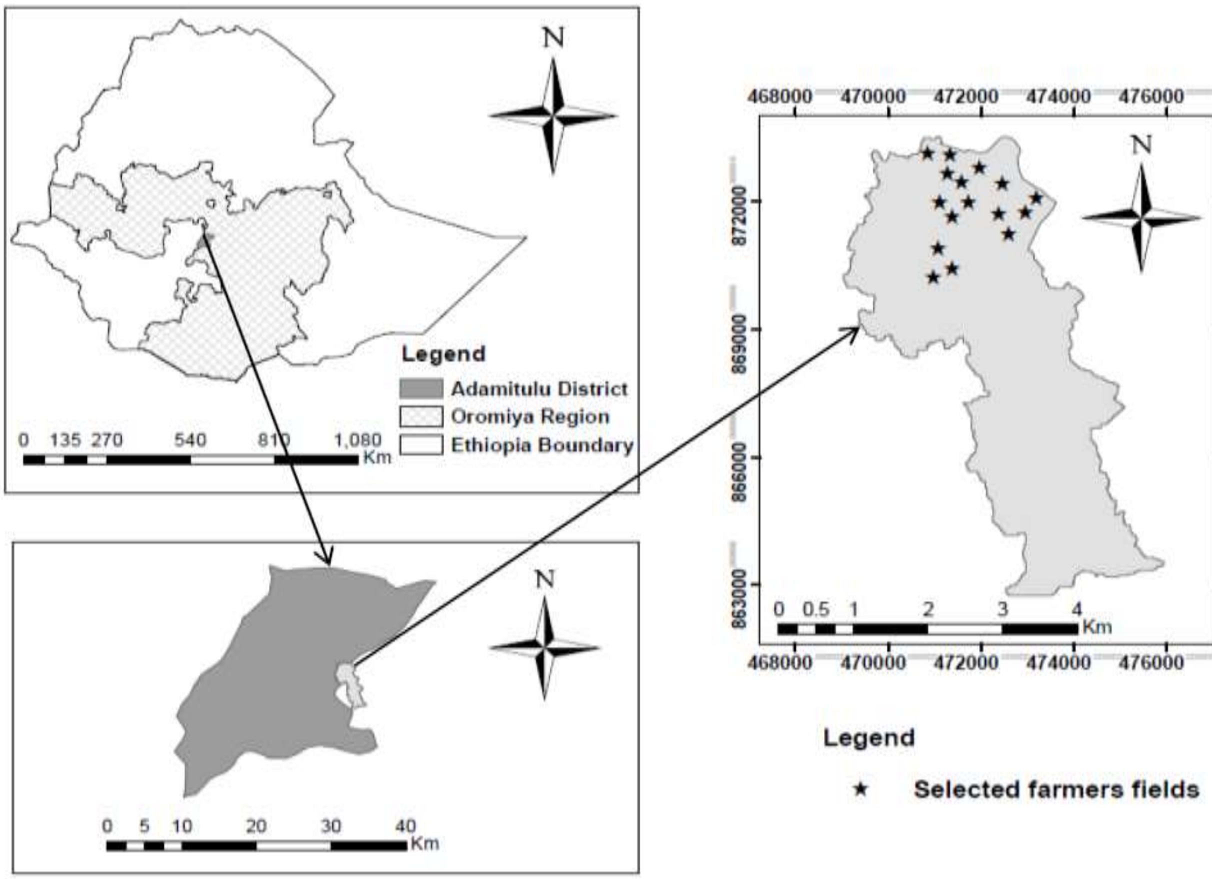

Figure 1. Location map and sampling fields.

Ethiopia lies between latitudes 4°N and 18°N, there is only a small variation in day length both between season and latitudes and the area is suitable for short-day plants.

Climate and land use

The metrological data obtained from an automatic weather station installed in the study area indicated that an average relative humidity is 46.5% during the dry season and 75.5% during the wet season. The average minimum temperature is 19.2°C and the average maximum temperature is 27.5°C. The mean annual rainfall in the area ranges from 600 to 850 mm and the rainfall pattern is erratic and unreliable (Figure 2). However, annual average potential evapotranspiration is approximately 1200 mm which signifies the importance of irrigated agriculture to fill the gap. Geology of the area is characterized by tertiary and quaternary age rhyolite and basalt volcanic materials (FAO, 1984; Giday et al., 1990; Legesse and Ayenew, 2006).

The major soil type exhibited in the area is Solonchacks (Alemayehu et al., 2016), mainly developed from evaporates and salt-rich parent materials (Brady and Well, 2002; Halcrow, 2008). According to Wendemeneh et al. (2020), the properties of the soil in the area ranges from slightly alkaline to strongly alkaline in reaction and dominantly sandy loam in texture. The topography is characterized by plain to undulated hills located adjacent to the escarpment of the central part of the Ethiopian mountain channels. The major land-use types that are practiced in the area are cultivated land which is concentrated in flat areas and grazing land that is mainly located in the hilly area and lakeshores. Cropping practices are dominated by horticultural crop production during the irrigation seasons and cereal production during rainy seasons. The major cash crops grown in the area are tomato, cabbage, onion, and beans whereas maize, teff, and wheat are considered as main food crops (Wendemeneh et al., 2020). The natural vegetation is situated nearby lake and river banks and composed of bushes and *Acacia* species.

Experimental setup and treatments

The experiment was carried out on 16 selected farmer's fields in the area for two consecutive years (2016 - 2017) during dry seasons. The farmers were further categorized into two groups based on water sources used and irrigation water management practice employed. Irrigation water monitoring tool, wetting front detector (WFD) was installed under four farmers' fields from each group. WFD is a funnel-shaped tool buried in the soil within the root zone of the crops to monitor the soil water status during cropping seasons. When a wetting front reaches optimum depth, the detector indicator pops up and irrigators should stop watering their fields. Detectors are usually placed in pairs, about one third and two thirds down the active root zone. While on the other eight farmers field (four from each group) farmers' usual practice (FP) was employed as a means of on-farm agricultural water management practices.

The treatments comprised two water sources and on-farm water management practices (Table 1). The experiment aimed to

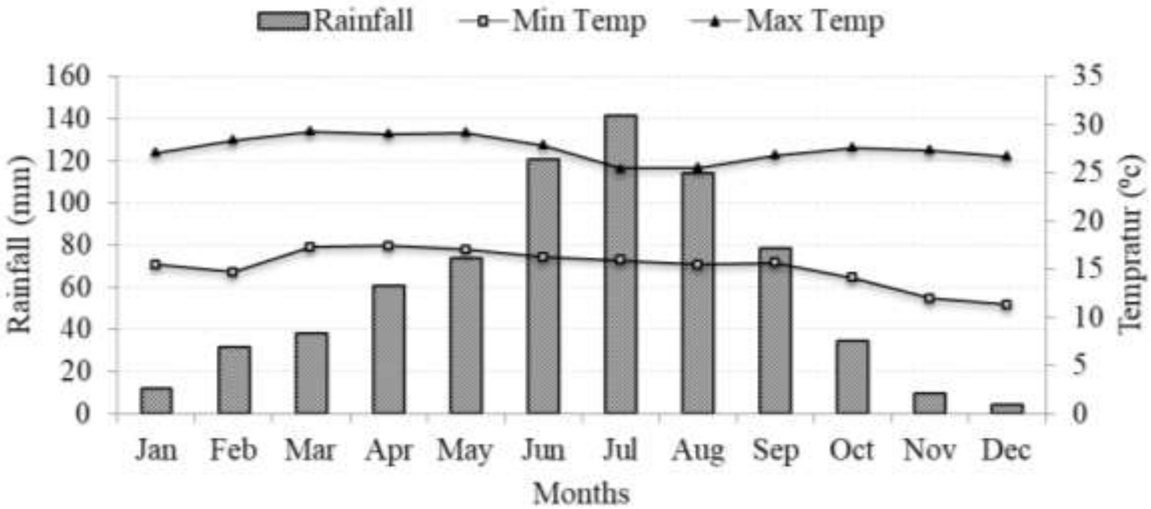

Figure 2. Mean monthly rainfall and temperature of the study area (1997 - 2017).

Table 1. The treatments and experimental setup of the study in the area (2016 - 2017).

Treatment code	Irrigation water source	Irrigation management practices	No. of farmers involved	Remark
Tr-1	SW	WFD	4	All of the farmer's grown leafy cabbage
Tr-2	SW	FP	4	
Tr-3	GW	WFD	4	
Tr-4	GW	FP	4	

Tr; Treatments, SW; Surface water, GW; Groundwater, WFD; Wetting front detector, FP; Farmers practice.

evaluate the effect of on-farm water management practices and the source of irrigation water used on soil quality in the area. The area of each experimental plot was 250 m^2 (25 m × 10 m). The spacing between rows was 60 cm and between plants was 35 cm. The seedling of leafy cabbage was prepared in a common place for all involved farmers. The transplanting of seedlings was done similarly at the beginning of February for each growing season under all farmers' fields. All post-planting field management practices were performed just after planting up to the end of cropping seasons. All important field data were collected in an organized manner from day one up to the end of cropping seasons.

Data collection

Soil sampling was performed in February and May at the beginning and end of each growing season for two consecutive years (2016 - 2017). It was carried out during the dry season to see the effect of irrigation practice on soil salinity. Composite soil samples were collected from 16 different farmer's fields with the help of hand auger for laboratory analysis (Figure 3). To account for depth effect on soil salinity, from six farmers (3 from each water source) field soil samples were collected from three layers; 0-30, 30-60, and 60-90 cm depth in each growing season. Samples were dried at room temperature then ground and sieved in 250 µm and subjected to a series of physicochemical analyses. The analyzed parameters were: texture, pH, electrical conductivity (EC), total nitrogen, organic carbon, phosphorus, cation exchange capacity (CEC), exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+).

Water sampling was done at the beginning and end of each growing season during the investigation period (Figure 3). It was carried out mainly to examine the effect of irrigation water sources on soil salinity in the area. The water samples were collected from two abstraction points along the river and four boreholes that farmers used for irrigating their crops. Totally six water samples were collected using plastic bottles in each growing season for laboratory analysis. The bottles used for the sample collection were washed thoroughly with detergent to make it clean for sample collection. The bottles were filled to the top, sealed, and labeled with a unique code number throughout the laboratory analysis period to enhance the accuracy of analytical results. The collected water samples were preserved in the icebox, transported, and analyzed according to the standards set for irrigation water quality (Ayers and Westcot, 1985). The analysis determined the concentration of pH, EC, OC, CO_3^{2-}, HCO_3^-, Cl^-, K^+, Ca^{2+}, Mg^{2+}, Na^+, and B.

Laboratory analysis

Soil sample analysis

The important physicochemical properties of soil samples were analyzed using standard laboratory procedures. Soil texture was analyzed using the Bouyoucos hydrometer method following the procedures suggested by Day (1965). The bulk density (BD) was estimated from undisturbed soil samples following the procedures used by Blake (1965). Soil pH was determined using pH meter

Figure 3. Soil and water sample collection in the area at the beginning of the season.

while EC was determined by using a conductivity meter. Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934). The percentage OM of the soils was determined by multiplying the %OC value by a factor of 1.724. Available P and total N were tested following the procedure developed by Olsen et al. (1954) and the Kjeldahl procedure (Black, 1965), respectively. The ammonium acetate method was employed to determine the CEC and exchangeable bases (Black, 1965).

Soil salinization and sodicity resulting from poor irrigation practice become a major problem in irrigated agriculture. Salinization of the soils related to irrigation practice was determined by using the electrical conductivity of the saturated extract (ECe). As suggested by Ayers and Westcot (1985) the saturated extract (ECe) value above 4 dSm^{-1} are considered as saline soil. Soil sodicity is the process by which Ca^{2+} and Mg^{2+} on the soil exchangeable complexes are substituted for Na^{+} which in turn could affect soil structure. The SAR is a widely accepted index for characterizing the soil solution concerning its likely influence on exchangeable sodium. As suggested by Ayers and Westcot (1985), SAR was estimated by using Equation 1. The concentrations of all ions in Equation 1 are expressed in milliequivalents per liter.

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

Another important indicator of soil sodicity as a result of irrigated agriculture is the percentage of sodium on the exchange complex. The ESP was estimated by using Equation 2 as suggested by Landon (1991). The concentrations of all ions in Equation 2 are also expressed in milliequivalents per liter.

$$ESP = (Na/CEC) \times 100 \quad (2)$$

Total dissolved solids (TDS) were estimated by using Equation 3 as suggested by Landon (1991). All the ionic concentrations in Equation 3 are expressed in milligrams per liter.

$$TDS\ (mg/L) = EC(dS/m) \times K \quad (3)$$

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.

Water sample analysis

The analysis of physio-chemical parameters of the water samples was carried out using the standard laboratory procedures. Electrical conductivity (EC_w) and pH (H_2O) were determined using conductivity meter and pH-meter (Greenberg et al., 1992), respectively. Soluble Na^{+} and K^{+} were determined by a flame photometer (RTI, 1991) while soluble Ca^{2+} and were analyzed directly by the atomic absorption spectrophotometer (APHA, 1998). Chloride, carbonate and bicarbonate ions were measured by titrating against silver nitrate standard solution with potassium chromate indicator with a procedure from (Greenberg et al., 1992). Similarly, phosphorus, nitrate, and boron were determined by using spectrophotometric as described by AOAC (1990).

The use of poor quality can create four types of problems such as toxicity, water infiltration, salinity, and miscellaneous (Ayers and Westcot, 1985). As Raghunath (1987) and Michael (1992) emphasized that the evaluation of water quality for irrigation purpose should be considering four most popular parameters: EC/TDS, SAR, RSBC and chemical concentrations like Na, Cl, and B. For current irrigation water quality evaluation, those parameters were considered. Sodium adsorption ratio (SAR) of irrigation was estimated by using Equation 1 as suggested by Ayers and Westcot (1985). It is carried out to predict the danger of sodium accumulation in the soil as a result of irrigation practices. In addition to that, total dissolved solids (TDS) were also estimated by using Equation 3 to predict the concentration of ions in the soil. Residual sodium carbonate (RSC) existing in irrigation water was estimated by using Equation 4 as suggested by Raghunath (1987). All ions concentration in Equation 4 is also expressed in milliequivalents per liter.

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \quad (4)$$

Soluble sodium percentage (SSP) was estimated by using Equation 5 as suggested by Todd (1980). The presence of a high concentration of sodium ion in irrigation water could degrade soil structure due to its dispersing effect of clay particles. The concentrations of all ions in Equation 5 are expressed in milligrams per liter.

$$SSP = (Na+K/Ca+Mg+Na+K) \times 100 \quad (5)$$

The permeability of soil is affected by sodium, calcium, magnesium, and bicarbonate contents of irrigation water. The permeability index (PI) of irrigation water was estimated by using Equation 6 as suggested by Doneen (1964). In Equation 6, the concentrations of all ions are also expressed in milliequivalents per liter.

$$PI = \left(\frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \right) \quad (6)$$

Kelly's ratio (KR) is an equation developed for determining sodium related problems in irrigation water. The KR was estimated by using Equation 7 as described by Kelly (1963). The concentrations of all ions in Equation 7 are expressed in milliequivalents per liter.

$$KR = \frac{Na}{Ca + Mg} \quad (7)$$

Statistical analysis

Generalized linear model (GLM) procedure in the statistical package for the social science (SPSS) version 16 application was used in the analysis of the entire data. The general linear model (GLM) of two ways analysis of variance (ANOVA) was used to determine whether differences existed among experimental treatments concerning soil quality. The mean of each parameter was compared between irrigation water sources and management practices using a post hoc comparison test (Tukey's Honestly Significant Difference) to find exactly where the differences lie between the studied treatments. The probability level for determination of significance was 0.05.

RESULTS AND DISCUSSION

This study assessed the effect of on-farm water management practices and the source of irrigation water used on soil quality under a farmer's field condition in the area. Soil and water samples were collected before planting and after harvesting for two consecutive years. The results of laboratory analysis of soil and water samples for different parameters were recorded and the mean value of salinity indices obtained from the analysis of variance (ANOVA) for studied treatment is presented in Tables 3 and 4. The physicochemical property of irrigation water and some of its quality indicators are shown in Table 5. Correlation analysis carried out between soil and irrigation water quality parameters is shown in Table 6. The graphical presentation of irrigation water source and soil sampling time effect on soil quality in the area are also shown in Figures 4 and 5.

Effect of on-farm water management practices on soil salinity

The result of on-farm irrigation management practices and water sources used revealed that the majority of salinity parameters showed significant differences at P<5% among treatments. This implies that irrigation water management practices and sources of irrigation water have an impact on soil salinity build-up in the area. Moreover, about 64.3% of soil properties showed significant variations at P<5% among treatments at the end of the season. But, at the beginning of the season, only 42.9% of soil properties showed such variations (Table 3). This implies that variation of soil quality parameters is more pronounced at the end of the growing season compared with its initial values recorded at the beginning of the season. These variations might be attributed to management practices employed and irrigation water sources used during growing periods. In fact, throughout the study, Tr-1 and Tr-3 are designated for managed fields (WFD) while Tr-2 and Tr-4 are designated for unmanaged fields (FP). But, both fields were irrigated with surface and groundwater sources to see how water sources influenced soil fertility in the area.

The pH ranged from 8.13 (Tr-2) to 8.69 (Tr-4) and EC ranged from 0.61 dS/m (Tr-2) to 1.03 dS/m (Tr-4), respectively as shown in Table 3. The data indicate that lower and higher values for both parameters were observed in FP fields. But, both fields were irrigated with different water sources during the experimentation period. As clearly observed in Table 4, its value in WFD field conditions gets low (8.39) compared to its value (8.41) in FP fields. As compared to its initial value (pH=8.20), at the end of the season, pH values showed a slightly increasing trend. This may be attributed to the effect of treatments tried in the area under prevailing field conditions. The EC values did not show any significant variation among treatments. This implies that soil salinity levels were not as such influenced by on-farm water management practices employed and irrigation water sources used in the area. However, in both fields, its values showed an increasing trend compared to its initial values (Table 3). This may be attributed to irrigation management practices employed and irrigation water sources used during the study periods. Moreover, a higher value for both parameters was observed in groundwater irrigated fields throughout experimentation periods. This suggests that irrigation water source has pronounced effects on soil quality aside from management practices. However, the average value of both parameters (pH= 8.40; EC=0.84) remains below the limit (Table 2) in all treatments. Similar findings related to these parameters were also reported by Kefyalew and Kibebew (2016) and Hadera (2018) in the area.

The concentration of CEC and OMC showed significant variations among treatments at the end of the season. The values CEC showed a decreasing trend while OMC showed an increasing trend compared to their initial values (Table 3). This implies that both management practices and water sources influence soil fertility in the area. The highest OM content (4.9%) was observed at managed fields compared to unmanaged fields (3.1%). This suggests that on-farm water management practices can improve soil quality. Total nitrogen and available

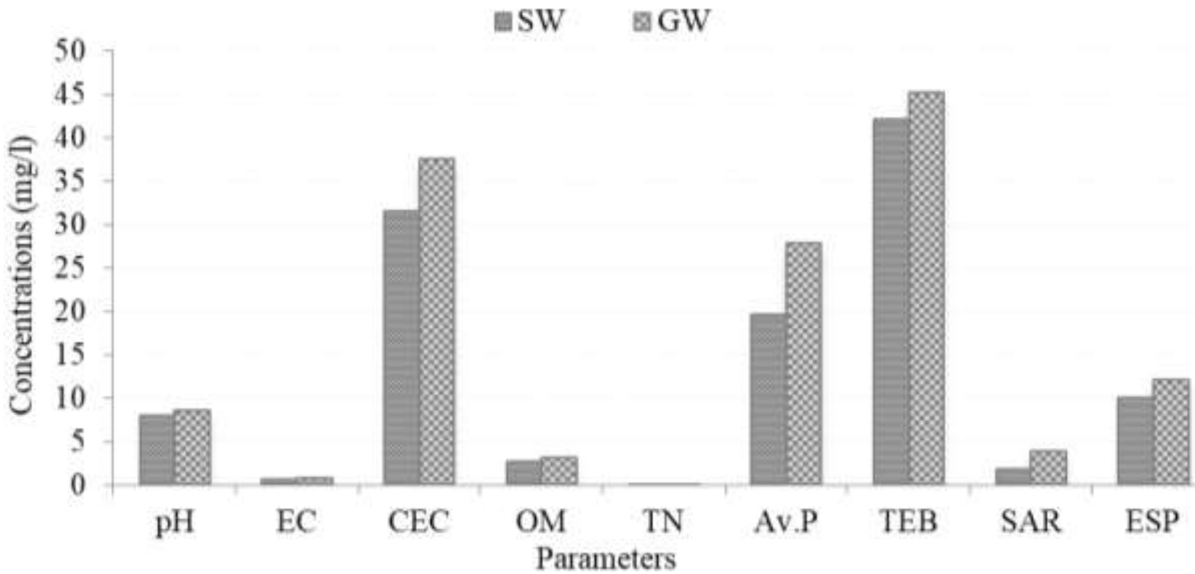

Figure 4. Graphical illustration of the effect of irrigation water source on soil salinity under farmer's field condition.

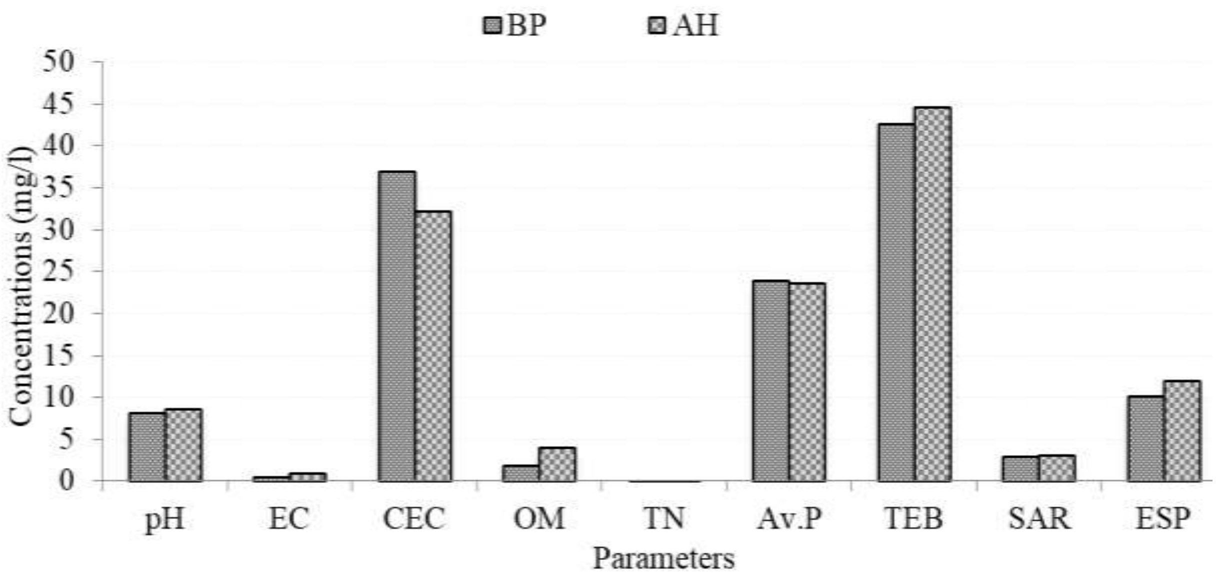

Figure 5. Graphical illustration of the effect of sampling time on soil salinity under farmer's field condition.

phosphorous values in the area were significantly varied at $P<0.05$ among studied treatments. This implies that treatment effects are noticeable and can influence soil fertility in the area. The concentration of these parameters also showed an increasing trend at the end of the season. This may also confirm that irrigation management and water sources could influence soil quality. Moreover, the high value of these parameters (TN=0.45%; AP=30 ppm) was observed under WFD installed fields as compared to FP fields (TN=0.22%; AP=17 ppm) (Table 3). This suggests that irrigation management practices can play an important role to manage soil fertility in irrigated fields through reducing leaching of nutrients. This finding was also agreed with other research findings reported by Hadera (2018).

As indicated in Table 3, the mean values of soil properties followed by the same letter in the same rows are not significantly different from each other. In fact, the values compiled in Table 3 shows how the concentration of studied soil properties varied among treatments during the study period. The values of exchangeable basis (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) are also show remarkable

Table 2. Soil and water quality parameters recommended for agricultural practices/purposes.

Parameter	Sample type	Symbol	Unit	Acceptable range	Source
Alkalinity/Basicity	Soil; Water	pH	0-14	6.5-8.4	
Electrical conductivity	Soil; Water	EC	dS/m	0-4	
Total dissolved solids	Soil; Water	TDS	mg/l	0-2000	
Sodium adsorption ratio	Soil; Water	SAR	meq/l	0-9	
Carbonate	Water	CO_3^{2-}	mg/l	0-3	Ayers and Westcot (1985)
Bicarbonate	Water	HCO_3^-	mg/l	0-519	
Chloride	Water	Cl^-	mg/l	0-355	
Boron	Water	B	mg/l	0-2	
Nitrate	Water	NO_3^-	mg/l	0-10	
Calcium	Soil; Water	Ca^{2+}	$Cmol_c$/kg; mg/l	0-20; 0-400	FAO (2006); Ayers and Westcot (1985)
Magnesium	Soil; Water	Mg^{2+}	$Cmol_c$/kg; mg/l	0.3-8; 0-60	FAO (2006); Ayers and Westcot (1985)
Sodium	Soil; Water	Na^+	$Cmol_c$/kg; mg/l	0.1-2; 0-1000	FAO (2006); Ayers and Westcot (1985)
Potassium	Soil; Water	K^+	$Cmol_c$/kg; mg/l	0.1-1.2; 0-2	FAO (2006); Ayers and Westcot (1985)
Phosphorous	Soil; Water	PO_4^{3-}	ppm; mg/l	5-25; 0-2	FAO (1980): Ayers and Westcot (1985)
Cation exchange capacity	Soil	CEC	$Cmol_c$/kg	15-40	FAO (2006)
Exchangeable sodium percent	Soil	ESP	%	<15	Landon (1991)
Organic matter content	Soil	OMC	%	0.86-5.17	Tekalign (1991)
Total nitrogen	Soil	TN	%	0.10-0.25	
Residual sodium carbonate	Water	RSC	meq/l	<2.5	Raghunath (1987)
Permeability index	Water	PI	%	>65	Doneen (1964)
Magnesium adsorption ratio	Water	MAR	%	<50	Raghunath (1987)
Soluble sodium percentage	Water	SSP	%	<60	Todd (1980)
Kelly ratio	Water	KR	meq/l	<1	Kelly (1963)

variations among treatments. This indicates that irrigation water management and water sources have noticeable influences on soil quality. All exchangeable basis except Ca^{2+}, showed an increasing trend at the end of the growing season. This increment may also be attributed to differences in irrigation management employed and water sources used. Because all of these parameters showed high values at the end of the season compared to their initial values. Higher values for these parameters are also observed in FP fields during the study periods (Table 3). Alemayehu et al. (2016) and Hadera (2018) reported similarly higher values for these parameters in the area.

The bulk density (BD) did not show any variation across the season and among the treatments (Table 3). But, relatively its higher value was observed in WFD installed fields (1.11 gcm^{-3}) compared with its value (1.07 gcm^{-3}) in FP fields. This may probably be due to differences in tillage practices and trampling effects of domestic animals freely grazing in the area. Moreover, its low value was observed at the end of the season compared with its initial value at the beginning of the season. This suggests that irrigation practice may have an impact on the physical property of the soil in the area.

As clearly observed in Table 3, total dissolved solutes (TDS) during the study periods did not show any variation among treatments. However, its values showed an increasing trend at the end of growing seasons under both field conditions. This suggests that on-farm water management practices slightly influenced salinity build-up in the area. Aside from management practices, irrigation water sources would also play a role in salinity build-up around the root zone. The average value of TDS in WFD installed fields is 528 mg/l compared with 547.23 mg/l in FP fields. This also confirmed that on-farm water management practices have an impact on soil salinity. Similar findings were also reported by Kefyalew and Kibebew (2016) and Alemayehu et al. (2016) in the area related to these parameters.

The sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) values during the study period showed significant variations at $P<0.05$ across the season and among treatments. This also highlights the importance of irrigation management to reduce the adverse effects of irrigation practices on soil quality in the area. Like others, these parameters are also shown an increasing trend at the end of growing seasons under

Table 3. The effect of irrigation water management practices on soil quality under farmer's fields.

Parameter	At the beginning of the season (BP)						
	Tr-1	Tr-2	Tr-3	Tr-4	Average	Sig.	LOS
pH	8.05[a]	7.99[a]	8.07[b]	8.71[a]	8.20	0.00	*
EC	0.56[a]	0.47[a]	0.48[a]	0.63[a]	0.54	0.67	NS
CEC	39.61[a]	32.08[a]	37.10[a]	39.17[a]	36.99	0.18	NS
OM	1.95[a]	1.98[a]	1.52[a]	1.88[a]	1.83	0.5	NS
TN	0.27[a]	0.29[a]	0.22[a]	0.28[a]	0.27	0.83	NS
AP	35.01[b]	17.35[a]	22.33[a]	30.96[a]	26.41	0.05	*
K^+	3.12[a]	2.74[a]	3.14[a]	3.47[a]	3.12	0.34	NS
Ca^{2+}	26.55[b]	22.64[a]	22.65[a]	19.75[a]	22.9	0.02	*
Mg^{2+}	11.86[a]	15.56[a]	13.96[a]	10.62[a]	13.09	0.26	NS
Na^+	3.85[a]	2.63[a]	2.79[b]	5.54[a]	3.70	0.05	*
BD	1.23[a]	1.11[a]	1.20[a]	1.21[a]	1.20	0.78	NS
TDS	358.42[a]	307.30[a]	300.77[a]	403.24[a]	342.44	0.67	NS
SAR	2.53[b]	1.82[ab]	2.63[a]c	5.31[a]	3.10	0.00	*
ESP	11.29[a]	8.31[a]	7.92[b]	13.19[a]	10.18	0.05	*
	At the end of the season (AH)						
pH	8.23[a]	8.13[b]	8.55[a]	8.69[a]	8.40	0.00	*
EC	1.04[a]	0.61[a]	0.65[a]	1.06[a]	0.84	0.25	NS
CEC	29.28[a]	25.31[b]	34.49[ab]	39.79[a]	32.22	0.00	*
OM	5.01[a]	2.25[b]	4.81[ab]	3.86[a]c	3.98	0.00	*
TN	0.38[a]	0.24[a]	0.51[a]	0.20[a]	0.34	0.14	NS
AP	30.99[a]	19.24[ab]	29.65[b]	28.82[b]	23.68	0.00	*
K^+	2.45[a]	2.26[a]	2.82[b]	4.10[a]	2.90	0.00	*
$Ca2^+$	23.22[a]	22.87[a]	43.76[a]	23.58[a]	28.36	0.36	NS
$Mg2^+$	7.98[a]	15.5[b]	8.13[a]	8.76[a]	10.09	0.00	*
Na^+	1.55[a]	3.91[b]	3.33[b]	5.27[b]	3.51	0.00	*
BD	1.12[a]	1.03[a]	1.10[a]	1.11[a]	1.09	0.34	NS
TDS	665.60[a]	416.00[a]	390.40[a]	678.40[a]	537.60	0.08	NS
SAR	2.68[a]	3.04[ab]	3.46[b]	4.53[b]	2.93	0.00	*
ESP	9.24[b]	15.43[a]	10.39[a]	13.10[a]	11.04	0.00	*

Tr; Treatments, * Significant at ≤ 5%, NS; Non-significant, LOS; Level of significant, BP; Before planting, AH; After harvesting

both WFD and FP fields' conditions in the area. This might be attributed to the effect of irrigation management practices and the source of irrigation water used in the area. It also clearly expresses how treatment influences soil quality. Furthermore, the average value of ESP in WFD fields (9.8%) is lower than the value of ESP in FP fields (14.3%). Hence, irrigation management practices have played a noticeable role in maintaining soil quality in the area. This finding also agreed with other findings reported by Alemayehu et al. (2016), Kefyalew and Kibebew (2016) and Hadera (2018).

Effect of irrigation water source on soil salinity

The farmers in the area used both surface and groundwater for irrigating their fields. As expressed in Figure 4, almost all of the studied soil properties showed an increasing trend in groundwater irrigated fields compared to surface water irrigated fields. This may be attributed to the difference in the quality of irrigation water used during the investigation period. It also supports water analysis results in which all studied parameters showed high concentration under groundwater samples. The pH and EC of the soil showed a slightly increasing trend in groundwater user's field. This also confirms that the irrigation water source has an impact on soil quality in the area. Hence, paying attention to the quality of groundwater is very important as long as it is supposed to be used for irrigation purposes. And also periodic assessment of its influence across the field is very important to sustain irrigated agriculture in the area. Soil OM, AP, and CEC showed a clearly observable increase in the case of groundwater user fields compared to

Table 4. Variation of soil salinity parameters across sampling depths in farmer's field condition.

Parameter	Surface water irrigated fields			Groundwater irrigated fields			Average	Sig	LOS
	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm			
pH	7.86^{a}	7.77^{b}	7.48^{ab}	8.33^{a}	8.02^{a}	7.88^{a}	7.89	0.01	*
EC	0.63^{a}	0.42^{a}	0.27^{a}	0.78^{a}	0.72^{a}	0.50^{a}	0.55	0.23	NS
CEC	45.03^{a}	37.20^{a}	32.26^{a}	39.48^{a}	38.30^{a}	35.08^{a}	37.89	0.08	NS
OM	2.03^{a}	1.44^{a}	1.14^{b}	2.39^{a}	1.51^{a}	1.06^{a}	1.60	0.03	*
TN	0.28^{a}	0.15^{a}	0.09^{b}	0.24^{a}	0.10^{a}	0.08^{a}	0.16	0.01	*
Av.P	71.27^{a}	59.10^{a}	36.07^{a}	47.70^{a}	39.51^{a}	30.58^{a}	47.37	0.18	NS
Ca^{2+}	29.92^{a}	24.14^{a}	19.98^{a}	22.25^{a}	21.81^{b}	17.62^{a}	22.62	0.00	*
Mg^{2+}	9.89^{b}	5.59^{a}	5.28^{ab}	9.81^{b}c	5.58^{a}	4.93^{a}	6.85	0.00	*
K^{2+}	2.89^{a}	3.63^{a}	3.95^{a}	4.19^{a}	4.09^{a}	4.09^{a}	3.80	0.10	NS
Na^{2+}	2.98^{a}	1.30^{a}	1.18^{a}	4.47^{a}	4.49^{a}	3.64^{a}	3.01	0.12	NS
TDS	405.12^{a}	270.93^{a}	173.87^{a}	495.79^{a}	448.00^{a}	321.07^{a}	352.46	0.24	NS
SAR	2.75^{a}	1.55^{a}	1.33^{b}	4.26^{a}	3.73^{a}	3.38^{a}	2.83	0.05	*
ESP	7.92^{a}	3.74^{a}	3.72^{b}	10.31^{a}	11.27^{a}	10.13^{a}	7.85	0.05	*

*Significant at ≤ 5%, LOS; Level of significance, NS; None significant.

Table 5. Chemical properties of irrigation water across the source in the area.

Parameter	SW-1	SW-2	GW-3	GW-4	GW-5	GW-6	ASW	AGW	TA
pH	8.20	7.98	8.10	8.23	7.83	7.93	8.09	8.02	8.06
EC	0.52	0.48	2.03	2.73	1.63	1.91	0.50	2.08	1.29
Na^{+}	255.85	262.8	398.75	564.00	388.75	445.75	259.32	449.31	354.32
Ca^{2+}	39.30	38.08	65.55	45.05	60.55	69.13	38.69	60.07	49.38
CO_3^{2-}	32.75	27.50	44.25	52.75	79.00	81.00	30.13	64.25	47.19
HCO_3^{-}	314.50	280.25	932.50	1028.80	960.00	910.75	297.37	958.01	627.69
K^{+}	189.00	228.50	370.50	367.75	302.75	311.00	208.75	338.00	273.38
Mg^{2+}	26.50	27.35	49.50	50.63	57.60	58.65	26.92	54.10	40.51
Cl^{2+}	35.75	37.25	69.75	216.75	111.25	145.75	36.50	135.88	86.19
NO_3^{-}	96.10	126.88	38.80	26.63	44.18	32.83	111.49	35.61	73.55
PO_4^{3-}	0.62	0.79	1.12	0.99	1.09	0.87	0.71	1.02	0.87
B	0.05	0.08	0.52	0.75	0.28	0.14	0.06	0.42	0.24
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	79.90	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
TDS	331.36	306.4	1295.40	1742.90	1041.60	1222.20	318.88	1325.53	822.2
MAR	80.69	79.19	94.29	95.40	93.21	94.10	79.94	94.25	87.1
PI	91.37	92.24	90.46	97.16	87.47	88.56	91.81	90.91	91.36

SW: Surface water, GW: Groundwater, ASW: Average value of surface water, AGW: Average value of groundwater, TA: Total average value.

surface water user fields. This implies that a high concentration of these parameters under those fields most probably due to the overuse of agricultural inputs. Similar results were also reported by Seid and Genanew (2013) and Hadera (2018).

It can be stated from the graph that the total exchangeable bases showed a slightly increasing trend in groundwater user fields. However, Mg^{2+} concentration gets high under surface water user fields and this may be related to the easily leachable nature of the element. Generally paying attention to the implementation of certain irrigation water management practices is critical to maintaining soil fertility in the area. Moreover, considering groundwater quality in the future is also very important to sustained irrigated agriculture in the area.

Wendemeneh et al. (2019) also reported very high concentration of these parameters in groundwater sources compared to surface water. This might be the

Table 6. Correlation analysis among water quality parameters, soil quality parameters and between water and soil quality parameters in the area.

Parameter	pH$_w$	EC$_w$	Ca$_w$	Mg$_w$	K$_w$	Na$_w$	TN$_w$	AP$_w$	SAR$_w$	pH$_s$	EC$_s$	Ca$_s$	Mg$_s$	K$_s$	Na$_s$	AP$_s$	SAR$_s$
pH$_w$	1	0.86	-0.73	-0.77	0.84	0.96[b]	0.24	0.43	0.99[a]	0.66	0.81	-0.03	0.66	0.60	0.96[b]	0.37	0.99[a]
EC$_w$		1	-0.28	-0.96[b]	0.85	0.99[a]	0.34	0.81	0.88	0.89	0.51	-0.29	0.32	0.21	0.64	-0.07	0.75
Ca$_w$			1	0.13	-0.40	-0.42	-0.09	0.30	-0.67	-0.01	-0.78	-0.23	-0.73	-0.79	-0.83	-0.72	-0.80
Mg$_w$				1	-0.91	-0.96[b]	-0.10	-0.90	-0.83	-0.98[b]	-0.53	0.10	-0.38	-0.24	-0.61	0.02	-0.70
K$_w$					1	0.86	-0.19	0.69	0.91	0.90	0.82	0.27	0.73	0.62	0.84	0.39	0.87
Na$_w$						1	0.34	0.72	0.94	0.84	0.60	-0.24	0.42	0.32	0.74	0.05	0.84
TN$_w$							1	0.09	0.14	-0.05	-0.34	-0.96[b]	-0.52	-0.51	-0.12	-0.62	0.02
AP$_w$								1	0.51	0.95[b]	0.16	-0.23	0.03	-0.13	0.22	-0.36	0.32
SAR$_w$									1	0.74	0.84	0.05	0.69	0.62	0.95[b]	0.39	0.99[a]
pH$_s$										1	0.50	0.01	0.38	0.24	0.54	-0.01	0.62
EC$_s$											1	0.56	0.97[b]	0.96[b]	0.97[b]	0.82	0.93
Ca$_s$												1	0.73	0.74	0.36	0.84	0.21
Mg$_s$													1	0.99[a]	0.90	0.92	0.82
K$_s$														1	0.87	0.96[b]	0.78
Na$_s$															1	0.71	0.99[a]
AP$_s$																1	0.58
SAR$_s$																	1

[a]Correlation is significant at $p < 0.01$; [b]Correlation is significant at $p < 0.05$; Subscript letters; w-stands for water and s-stands for soil.

reason why majority of salinity parameters showed high values under groundwater irrigated fields compared to surface water irrigated fields in the area. Seid and Genanew (2013) and Hadera (2018) reported similar findings concerning the source of irrigation water effects on soil salinity in the area.

As expressed in Figure 5, the majority of the studied soil salinity parameters showed an increasing trend over time in the area. This implies that irrigation has contributed considerably to salinity buildup in the area. However, some parameters such as OMC and TN showed a slightly decreasing trend over time. Since year-round cultivation without appropriate management practices could reduce their concentration in soil due to the oxidation process. The pH of the soil has not been shown, as such a remarkable change during the entire study periods in the area. This implies that the effect of irrigation under the farmer's field conditions could not affect the alkalinity of the soil. The remaining soil properties such as EC, AP, and exchangeable cations have shown considerable variation with time.

As clearly observed from Figure 5, their concentration increases over time in the area due to irrigation practices and in the future, it may affect the fertility/salinity of the soil. Hence, paying attention to the implementation of certain irrigation management practices is crucial in the area. The use of irrigation as a means of crop production without considering management issues could negatively affect the productivity of the soil. As compared with the previous findings reported by Alemayehu et al. (2016) and Kefyalew and Kibebew (2016), the present finding gets high in terms of salinity probably due to intensive use of agricultural inputs including the amount of water applied in the field. Hence, there is a restriction on the use of land for irrigation purposes since a high concentration of those cations will affect salinity sensitive crops. Therefore, time-based data is very crucial for certain soil quality parameters that show change with time to develop a mitigation strategy.

Variability of soil salinity across the depth

The spatial variability of soil properties across the depth (surface, sub-surface, and subsoil) is shown in Table 5. As the results indicated in Table 4, about 54% of the studied quality parameters showed a significant difference at $P<0.05$ across sampling depths. The remaining 46% of soil properties did not show such variations across the depth. This suggests that irrigation water sources used to cultivate crops could influence salinity parameters across the depth. As the results indicated in Table 4, all irrigated fields soil across the depth are non-saline and non-sodic (Ayers and Westcott, 1985; Abrol et al., 1988). The analysis of the soil samples revealed that the soil reaction ranged from moderate to slightly alkaline, which is not unexpected for soils of the arid and semiarid region. The spatial variability pH for the surface, subsurface, and subsoil showed significant difference at $P<0.05$ across the depth and source of water used. The values of pH across the depth ranged between 7.5 (subsoil) and 8.3 (surface soil) and the highest value observed in groundwater irrigated fields. It suggested that alkalinity is more pronounced at surface soil irrigated with groundwater.

TDS values across the depth under both water sources irrigated fields did not show such variation. And also relatively its higher value was observed at surface soils in groundwater irrigated fields. This implies that irrigating the fields with groundwater could influence soil salinity buildup in the area. Hence, the use of groundwater for irrigation needs special attention to mitigate its adverse effects on soil quality. As its use without considering any management options could aggravate salinity problems in the area. However, its values remain below the critical limit (4 dS/m) suggested for soil salinity problem (Table 2). These findings agreed with previous findings reported by Halcrow (2008) and Alemayehu et al. (2016).

As indicated in Table 4, the mean values of soil properties followed by the same letter in the same row are not significantly different from each other. The spatial variability of SAR for the surface, sub-surface, and subsoil are shown in Table 4. As shown in Table 4, its values ranged from 1.3 to 4.3, and the highest value was observed at the surface layer in groundwater irrigated fields. In addition to that, it also showed remarkable variation across the depth of investigated fields. During the investigation period, its values showed a declining trend across the depth under both water irrigated fields. Relatively, its higher values were also observed at groundwater irrigated fields. Hence, paying attention to groundwater quality is very important if the water is supposed to be used for irrigation. This finding agreed with the previous findings reported by Halcrow (2008), Kefyalew and Kibebew (2016) and Hadera (2018) which showed similarly high SAR values at surface soil in the area.

Table 4 shows how the concentration of studied soil properties varied across the depth of the soil. The values of ESP across the depth ranged from 3.74 to 11.27% and its higher value were observed in subsurface (30 - 60 cm) soil in groundwater irrigated fields. Its values showed significant variation across the depth and source of water used. Moreover, the analysis revealed that the sodicity problem was more pronounced under the groundwater user's fields. The SAR value, therefore, suggests that groundwater quality in the area should be taking into account during the planning of irrigation practices. However, ESP values across the depth of cultivated fields fell within the non-sodic class (less than 15) that suggested the occurrence of sodicity problems. This finding agreed with the previous findings reported by Halcrow (2008) in the area.

Chemical properties of irrigation water

Farmers in the area used both surface and groundwater sources for irrigating their fields. The research findings reported by Michael (1992) and Hillel (2000) showed that the quality of irrigation water influences soil fertility. Hence, the planning of any irrigation projects should be taken into account. Ayers and Westcot (1985) emphasized that water quality evaluation should focus on the farm level rather than at the project level. In this regard, the present evaluation was done at the farm level to know its influence on soil salinity aside from irrigation practices experienced in the area. As the results shown in Table 5, the values of pH and EC in the area ranged from 7.98 to 8.23 and 0.48 to 2.73 dS/m, respectively. The highest value in both cases was observed in groundwater samples. This may suggest that the use of groundwater for irrigation purposes is the most likely factor to influence soil quality compared to surface water. However, the average value of both parameters (pH=8.06; EC=1.29 dS/m) remains below critical limits (pH=8.50; EC=4.00 dS/m) recommended for irrigation uses (Table 2). In this regard, irrigation water used in the study area is found within a safe limit and suitable for irrigation. This finding is more or less similar to the previous study findings reported by Halcrow (2008) and Abay et al. (2016).

The concentrations of Ca^{2+} and Mg^{2+} in irrigation water varied from 38.08 to 69.13 mg/l and 26.50 to 58.65 mg/l, respectively (Table 5). The highest value for both parameters was also observed in groundwater samples. This implies that irrigating the farms with groundwater may increase salt contents in the soil which in turn could influence soil quality. However, the concentration of both parameters at both water sources remains below critical limits (Ca^{2+}=400 mg/l; Mg^{2+}=60 mg/l) recommended for irrigated agriculture (Table 2). The concentration of K^{+} in irrigation water ranged from 189.00 to 370.50 mg/l, respectively (Table 5). Similarly, its highest value during the study period was also observed in groundwater samples. Unlike others, the concentration of this parameter in both water sources showed a very high value compared to the limit (Table 2). This may probably be due to the nature of underlying rocks that are found in the area. Similarly, high value for this parameter was also reported by Halcrow (2008) and Abay et al. (2016) in the area.

Sodium (Na^+) concentration in irrigation water ranged from 255.85 to 564.00 mg/l (Table 5). The highest value for this parameter was observed in groundwater samples. Likewise, its concentration at both water sources remains by far higher than Ca^{2+} and Mg^{2+}. This suggests that irrigating farmlands with the water may increase the alkalinity of the soils. Besides, it may cause a toxicity problem on growing crops aside from physical deterioration of soil quality. Hence, paying attention to groundwater quality is critical to reducing such problems in the area. As the standards compiled in Table 2, however, indicated that the value of Na^+ is found within the permissible range. The other common toxic ions found in irrigation water are chlorine (Cl^-) and Born (B). Their concentrations in the area varied from 35.75 to 216.75 mg/l and 0.05 to 0.72 mg/l, respectively as indicated in Table 5. The highest value for these parameters was also observed in groundwater samples. However, the concentrations of both parameters in studied water sources are found within an acceptable limit for irrigation (Table 2).

The value of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) in all sampling sources and locations varied from 27.50 to 81.00 mg/l and 280.25 to 1028.80 mg/l, respectively (Table 5). The highest value for these parameters is observed in groundwater samples. This also reflects how groundwater quality deserves considerable attention in the area. The concentration of CO_3^{2-} at both water sources remained above the limit (Table 2). The values of HCO_3^- are found within the range in surface water while remained above in groundwater (Table 2). This data also suggests the use of water for agricultural purposes may cause negative impacts on soil quality. Similarly, high values for these parameters were also reported by Halcrow (2008) in the area. Nitrate (NO_3^-) and phosphate (PO_4^{3-}) values in the area are ranged from 26.63 to 126.88 mg/l and 0.62 to 1.12 mg/l, respectively as shown in Table 5. The highest value for NO_3^- was observed in surface water while for PO_4^{3-} in groundwater samples. The high concentration of both parameters in the area may be attributed to the miss-use of agricultural inputs. Such type of farming system needs intensive use of agricultural inputs which in turn could favor the loss of nutrients drained to water sources. The concentration of NO_3^- in both water sources remains above the limit (10 mg/l) while PO_4^{3-} was found within the range (Table 2).

The SAR value of irrigation water in the present study area ranged from 7.43 to13.45 meq/l (Table 5). This implies that the observed values are relatively high and it might be due to the lower value of Ca^{2+} and Mg^{2+} compared to Na^+. The highest value was observed in groundwater samples compared to surface water samples. Water having SAR values less than 9 is considered as safe for irrigation uses (Table 2). In this regard, surface water average SAR value (AS=7.56) is found within the limit and suitable for irrigation. However, groundwater samples average SAR value (AG=10.52) remains beyond this limit and have a limitation on use for irrigation purpose. The value of RSC in the area ranges from 0.99 to 10.82 meq/l (Table 6). The highest value for this parameter was observed in groundwater samples compared to surface water. The water has a high concentration of carbonates that could increase sodium hazards in the area as it favors the precipitation of Ca^{2+} and Mg^{2+}. As the standards indicated in Table 2, RSC value in groundwater samples remain beyond the limit and have a limitation on the use of it for irrigation purposes.

The TDS values in the study area ranged from 306.40 to1742.90 mg/l (Table 5). Like others, its highest value was also observed in groundwater samples. This implies that groundwater quality is an issue in the area and needs due attention. The SSP and KR are also widely used parameters for evaluating the suitability of water quality for irrigation. Because excess sodium concentration in irrigation water produces undesirable effects on soil and crops. The values of SSP below 60% (Tod, 1980), KR <1 (Kelly, 1963) is considered good and safe for irrigation. However, both surface and groundwater samples' values in the area are shown above this limit (Table 5). This also suggests irrigating the fields with the water may cause sodium related problems. Similarly, MAR values under both cases found above the critical limit (MAR <50%) suggests it may influence the uptake of Ca^{2+} by crop plants. The permeability index (PI) is used to evaluate the effect of long term use of irrigation water on soil quality. Its value in the area is varied from 87.47 to 97.16% (Table 5). The average value of PI in both sampling cases (sources) remains similar during the study periods. According to the standards indicated in Table 2, its values are found within acceptable limits for irrigation uses.

Correlation analysis between soil and water quality parameters

Pearson's correlation analysis was carried out in order to explore the magnitude and direction of relationships between soil and water quality parameters in the study area (Table 6). The results showed that certain quality parameters between soil and water showed a significant relationship with each other, whereas others did not show such a relationship among themselves. As indicated in Table 6, the pH was significantly and positively correlated with Na_w (r = 0.96) and SAR_w (r = 0.99). This relationship indicated that irrigation water used in the area has an impact on soil alkalinity. Similarly, the SAR_s was significantly and positively correlated with Na_w (r = 0.95) and SAR_w (r = 0.99) (Table 6). This was also reconfirmed through the positive relationship (non-significant) that exists between the majority of soil and irrigation water quality parameters in the area. Hence, irrigators should consider the quality of irrigation water during the planning of irrigation practices in the area as it influences soil quality. The concentration of available phosphorous in soil was strongly correlated with its concentration in irrigation water (r = 0.95). This strong relation regarding available phosphorous probably suggesting that irrigation water has also contributed to the occurrence of a high amount of available phosphorous observed in irrigated fields in the area (Table 3). In general, there is sufficient evidence to conclude that majorities of soil properties highly influenced by irrigation water quality because in all cases the correlation coefficients were significantly different from zero. Therefore, irrigation management practices should also take the quality of irrigation into account during the planning of irrigation practices to maintain soil fertility in the area.

CONCLUSIONS AND RECOMMENDATIONS

Soil salinity is the major factor limiting agricultural productivity in irrigated fields located in arid and semi-arid regions. Thus, monitoring salinity builds-up under irrigated fields through implementing different management practices is very important to sustain agricultural practices in such areas. Therefore, this study was conducted to evaluate the effect of irrigation water management practices on soil salinity under farmer's field conditions at Bochessa village for two consecutive years. In addition to that, it also assessed the influence of irrigation water sources on soil productivity across the depth of sampled fields in the area. The results revealed that on-farm water management practices and water sources used highly influences the salinity level of irrigated fields in the area. The majority of the investigated salinity parameters showed significant differences at P<5% among treatments. Besides, a variation of soil quality parameters is more pronounced at the end of the growing season compared with its initial values. The variation in concentration of the parameters might be due to management practices employed and irrigation water sources used during growing periods. Since high values for all of these parameters were observed under the farmer's practice (unmanaged fields) during entire study periods. Moreover, this investigation points out the different signs of soil quality degradation in the area as confirmed by the change in soil chemical properties.

The results further point out that alkalinity of the soil influenced by on-farm water management practices while salinity did not as such influence with such practices. Because the value of pH showed remarkable variation across treatment while EC did not show such variations. However, in both fields, their values show an increasing trend over time. Moreover, higher values for both parameters were observed under groundwater irrigated fields. This also implies that the irrigation water source has pronounced effects on soil quality. The concentrations of other properties such as CEC, OM, TN, and AP show significant variation among treatments, and their values showed an increasing trend over time. Moreover, higher values for these parameters were observed under managed fields. This suggests that irrigation water management practices can play an important role to maintain soil fertility. The SAR and ESP values during the study period showed significant variations among treatment. This also confirms that management practices and irrigation water sources have a meaningful impact on soil quality in the area. Hence, paying attention to improved management practices and quality of groundwater is very important to run agricultural practices in a sustained manner. In general, almost all studied parameters showed remarkable variation with time and in the future, both soil and water should be tested systematically to assess salt build-up under irrigated fields.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The author thanks the Arbaminch University and International Water Management Institute for their financial and technical support, Professor K. R. Sabu (expatriate staff at Arbaminch University) who edited the manuscript on a volunteer basis and Mr. Gemeda Dabi who assisted the team during data collection time.

REFERENCES

Abay C, Anbese A, Zelalem S (2016). Assessment of Surface and Ground Irrigation Water Quality for Small Scale Irrigation in East Shoa Zone of Oromia, Ethiopia. International Journal of Natural Resource Ecology and Management 1(2):25-31.

Abrol IP, Yadov SP, Massoud FI (1988). Salt affected soils and their management. FAO Soil Bulletin 39, Rome.

Alemayehu K, Sheleme B, Jeff S (2016). Characterization of problem soils in and around the south-central Ethiopian Rift Valley. Journal of Soil Science and Environmental Management 7(11):191-203.

Al-Ghobari HM (2011). Effect of Irrigation Water Quality on Soil Salinity and Application Uniformity under Center Pivot Systems in Arid Region. Australian Journal of Basic and Applied Sciences 5(7):72-80.

Association of Analytical chemists (AOAC) (1990). Official Methods of Analysis of the Association Analytical chemists. 15th ed. Virginia, USA.

American Public Health Association (APHA) (1998). Standard Methods for the Examination of Water and Waste Water. 17th ed. Washington, USA.

Ayers RS, Westcot DW (1985). Water quality for Agriculture. FAO irrigation and drainage paper No. 29, Rome.

Black CA (1965). Methods of soil analysis. American Society of Agronomy Part II, No 9. Madison, Wisconsin, USA. pp. 565-580.

Blake GR (1965). Bulk density analysis. In:C.A. Black (ed.). Methods of Soil Analysis. Am. Soc. Agron. Madison, Wisconsin, USA pp. 374-399.

Brady NC, Well RR (2002). The nature and properties of soil (13th Edition). Pearson Education Inc., Upper Saddle River. New Jersey, USA.

Central Statistical Agency (CSA) (2018). Compilation of Economic Statistics in Ethiopia. Addis Ababa, Ethiopia.

Day PR (1965). Hydrometer method of particle size analysis. In: C.A. Black (ed). Methods of Soil Analysis. American Society of Agronomy, Madison, Wisconsin, USA pp. 562-563.

Doneen LD (1964). Notes on water quality in agriculture in Water Science and Engineering Paper . Dept. of Water, Science and Engineering, Univ. of California, Davis, USA.

Edossa E, Nigussie D, Tena A, Yibekal A, Lemma D (2014). Irrigation Water Management Practices in smallholder vegetable crops production: The case of the central Rift Valley of Ethiopia. Science, Technology and Arts Research, Jan-March 2014 3(1):74-83.

Food and Agriculture Organization (FAO) (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO, Soil Bulletin 38/2, Rome.

Food and Agriculture Organization (FAO) (1984). Ethiopian geomorphology and soils (1:1,000,000 scales). Assistance to land-use Planning. Addis Ababa, Ethiopia.

Food and Agriculture Organization (FAO) (2006). Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer, and Plant Nutrition Bulletin 16, Rome.

Food and Agriculture Organization (FAO) (2017). Regional Overview of Food Security and Nutrition in Africa in 2016. The Challenges of Building Resilience to Shocks and Stresses. Accra, 39.

Giday W, Aronson JL, Walter RC (1990). Geology, geochronology, and rift basin development in the central sector of the Main Ethiopian Rift. Bulletin of the Geological Society of America 102:439-458.

Greenberg AE, Clesceri LS, Eaton AD (1992). Standard Methods for the Examination of Water and Wastewater (18thEd). American Public Health Association, American Water Works Association, Water Pollution Control Federation. Washington, USA.

Hadera D (2018). Impact of surface and groundwater salinity on soil and plant productivity in the central rift valley region around Lake Ziway. Journal of Environmental Sciences 6(3):067-084.

Halcrow Group Limited (2008). Rift Valley Lakes Basin Integrated Resources Development Master Plan Study Project Draft Phase 1 Report.

Heluf G (1987). Problems and Prospects of Salt Affected Soils in Ethiopia (Summary Literature Survey Report). Alemmaya University of Agriculture, Ethiopia.

Hillel D (2000). Salinity Management for Sustainable Irrigation: Integrating Science, Environment, and Economics. The World Bank, Washington, DC.

Hillel D (2004). Introduction to Environmental Soil Physics. Elsevier Academic Press, USA.

Husien A, Seboka S, Shifarraw W (2017). Assessment of irrigation water quality of lowlands in the Bale Zone, South Eastern Oromia, Ethiopia. Water Resources and Environmental Engineering 9(12):264-269.

Kefyalew A, Kibebew K (2016). Evaluation of the effect of salt-affected soil on selected hydraulic properties of soils in the Meki Ogolcha Area in East Showa Zone of Oromia Region. Ethiopia Journal of Biology, Agriculture and Healthcare 6:21.

Kelly WP (1963). Use of Saline Irrigation Water. Soil science 95:355-391.

Landon JR (1991). Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York.

Legesse D, Ayenew T (2006). Effect of improper water and land resource utilization on the central Main Ethiopian Rift lakes. Quaternary International 148:8-18.

Mesfin A (2015). Irrigation for Sustainable Agricultural Development in Ethiopia. Ethiopian Journal of Agricultural Science 25:31-44.

Mesfin M (2001). Assessment of Soils of Irrigated Lands and Irrigation Water Quality concerning Salinity & Sodicity in Meki-Zuwai Area, Oromia Region. MSc Thesis Report, Alamaya University.

Michael AM (1992). Irrigation Theory and Practices. Vikash Publishing House Pvt. Ltd., New Delhi, India. pp. 686-740.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorous in soils by extraction with sodium carbonate. USDA Circular 939:1-19.

Qureshi AS, Ertebo T, Mehansiwala M (2018). Prospects of alternative copping systems for salt-affected soils in Ethiopia. Journal of Soil Science and Environmental Management 9(7):98-107.

Raghunath HM (1987). Groundwater. Wiley Eastern Limited, New Delhi, India.

Royal Tropical Institute (RTI) (1991). Analytical Methods of the Laboratory for Soil, Plant, and Water Analysis. Part I: Methods for Soil Analysis. Amsterdam, the Netherlands.

Seid M, Genanew T (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 and Technology 7(5):167-174.

Tekalign T (1991). Soil, plant, water, fertilizer, animal manure, and compost analysis. Working Document No 13. International Livestock Research Center for Africa, Addis Ababa.

Tessema A, Mohammed A, Birhanu T, Negu T (2014). Assessment of Physicochemical Water Quality of Bira Dam, Bati Wereda, Amhara Region. Ethiopia. Journal of Aquaculture Research and Development 5:267.

Todd DK (1980). Groundwater Hydrology, 2nd edition. Wiley, New York, P 535.

Walkley A, Black CA (1934). An examination of different methods for determining soil organic matter and the proposed modifications by the chromic acid titration method. Soil Science 37:29-38.

Wendemeneh D, Ayana M, Partap S, Haileslassie A (2019). Evaluation of Surface and Ground Water Quality for Irrigated Agriculture in Ziway Area. Ethiopian Journal of Water Science and Technology 2:100-134.

Wendemeneh D, Ayana M, and Haileslassie A (2020). Spatiotemporal variation of irrigation water quality at Bochessa Watershed in Central Rift Valley of Ethiopia. African Journal of Environmental Science and Technology 14(2):70-82.