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Evaluation of drainage water quality for irrigation reuse in Kulfo and Hare irrigation command areas, southern Ethiopia

Edmealem Temesgen *, Guchie Gulie and Destaw Akili

Faculty of Water Resources and Irrigation Engineering, Arba Minch Water Technology Institute, Arba Minch University, Arba Minch, Ethiopia

*Corresponding author. E-mail: danicho1255@gmail.com

ET, 0000-0003-1513-870X

ABSTRACT

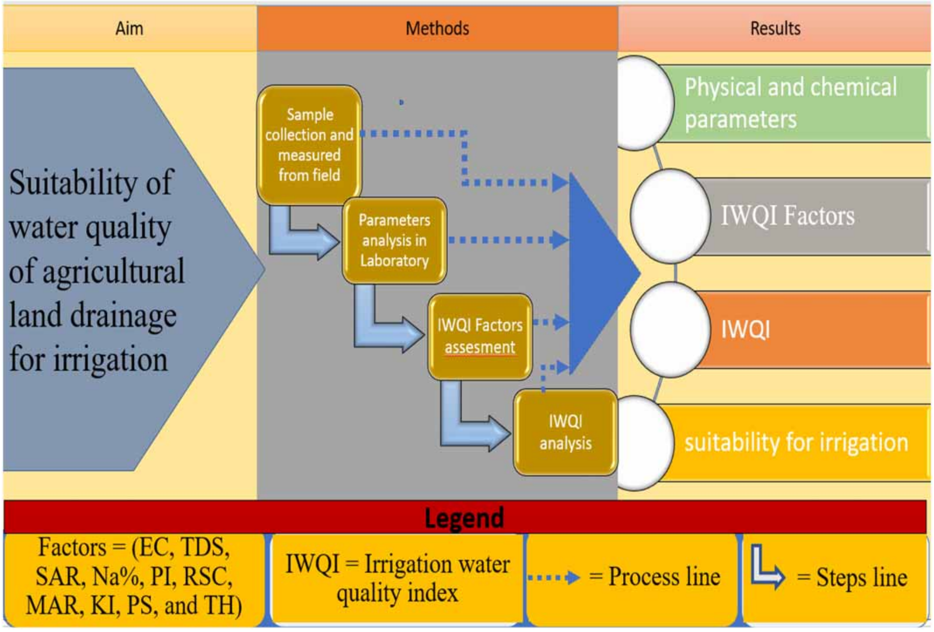
Water from agricultural drainage systems can be reused when its quality is good or blended with irrigation canal water to overcome the water shortage. The primary goal of this research was to determine the quality of surface drainage water in the Kulifo and Hare irrigation projects for irrigation reuse. Water quality was evaluated *in situ* and in the laboratory during the irrigation season of 2022. Turbidity, TDS, pH, EC, and DO were analyzed in the field using an Aqua meter. Fifty-seven water samples were collected and analyzed for the major cation (Na^+, Ca^{2+}, K^+, and Mg^{2+}) and anion (HCO_3^-, CO_3^{2-}, Cl^-, and SO_4^{2-}). The result of the drainage water quality index study, according to the water quality index for irrigation purpose reuse, ranged from 47.84 to 84.89. This indicated that the suitability of drainage water reuse for irrigation purposes was categorized as 'poor to very poor,' except in Shara community-managed farms. Therefore, to avoid the impact on soil quality for crop production due to the hazard of poor agricultural drainage water for irrigation reuse in the study area, it needs to be treated before being reused for irrigation purposes, except at the Shara irrigation community-managed farm.

Key words: irrigation reuse, irrigation water quality, surface drainage water, water quality index

HIGHLIGHTS

- Drainage water quality suitability for irrigation purposes.
- Chemical and physical factors affect the drainage of water quality for irrigation reuse.
- Scientific evidence and appropriate agricultural drainage water quality index.
- Agricultural land drainage water quality suitability for irrigation water reuse.
- Aqua meter used direct measure of water quality factors resulting in the field.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water is essential for irrigated agriculture (Shamsur *et al.* 2017). However, irrigated agriculture productivity and sustainability are dependent not only on an adequate supply of water but also on the quality of irrigation water. Irrigation water quality is critical for crop yield, soil productivity, and environmental protection (Laze *et al.* 2016). If water from agricultural drainage systems is reused for irrigation, it can have a direct detrimental impact on soil productivity due to soil salinization (Ashour *et al.* 2021).

Good quality irrigation water is, thus, an important component of sustainable irrigated agriculture. Whereas, salinity, sodicity, and ion toxicity are the major problems of irrigation water as they affect soil quality and crop yield (Zaman *et al.* 2018). The chemical constituents of irrigation water can affect plant growth directly through toxicity or indirectly by altering the soil property and availability of nutrients (Ayers & Wescot 1985). In arid areas where rainfall does not adequately leach the salts from the soil, an accumulation of salts will occur in the crop root zone (Zaman *et al.* 2018).

The main sources of irrigation water for irrigated agricultural practices around Arba Minch are Kulfo and Hare Rivers. Hence, the source of irrigation water for the Amibara-irrigated agricultural farm and Arba Minch University research farm is the Kulfo River, whereas the Hare River is the source of irrigation water for the Shara and Chano community-managed small-scale irrigated agricultural practices. According to the Ethiopian climate classification, the irrigation command areas of Kulfo and Hare rivers are characterized by hot, semi-arid, warm temperatures, and tropical climates (Haji *et al.* 2021). The irrigation command areas of the Kulifo and Hare irrigation schemes (Amibara, Arbaminch University Research farm, Shara and Chano community-managed small-scale irrigation farms) are among the large irrigated agricultural areas in the Abaya-Chamo Lakes basin. These four irrigation command areas use surface irrigation systems and surface drainage systems. The command areas dispose the drainage water to Hare River, Abaya Lake, and Kulfo River. The drainage effluent is also reused for irrigation when there is the shortage of canal water. However, it is practiced without proper investigation of the drainage water quality for its suitability for irrigation.

To evaluate the water quality for irrigation, 'water quality indices' (WQIs) are employed. WQI is a unitless value distilled from a complex mathematical manipulation based on various hydrochemical properties (Pesce & Wunderlin 2000). Based on primary water quality parameters, WQIs such as Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Sodium Carbonate Residual (RSC), Residual Alkalinity (RA), Kelly's Ratio (KR) or Kelly's Index (KI), Permeability Index (PI), Magnesium Hazard (MH), Total Dissolved Ions (TDI), Magnesium Adsorption Ratio (MAR), and Total Hardness (TH) are well-established and used frequently.

Therefore, the primary aim of this research was to determine the suitability of water quality of surface drainage systems for irrigation reuse in the research area.

2. MATERIALS AND METHODS

2.1. Description of the study area

The study area of this work is located in the southwest of Lake Abaya and north of Arba Minch town in southern Ethiopia (Figure 1). It includes Amibara irrigated farm of Gamo Development Association, Arba Minch University research farm, Shara and Chano community-managed small-scale irrigation farms located between the longitudes 37°34′00″ and 7°39′00″ east, the latitudes 5°54′30″ and 6°11′30″ north, at an elevation of 1,203 m above mean sea level. The study area is about 454 km south of Addis Ababa. The catchment of Kulifo River covers 455 km^2 and the river is the main source of water for Amibara irrigated farm and Arbaminch University research farms, while the catchment of Hare River covers 183 km^2 and it is the main source of irrigation water for Shara and Chano community-managed small-scale irrigation command areas.

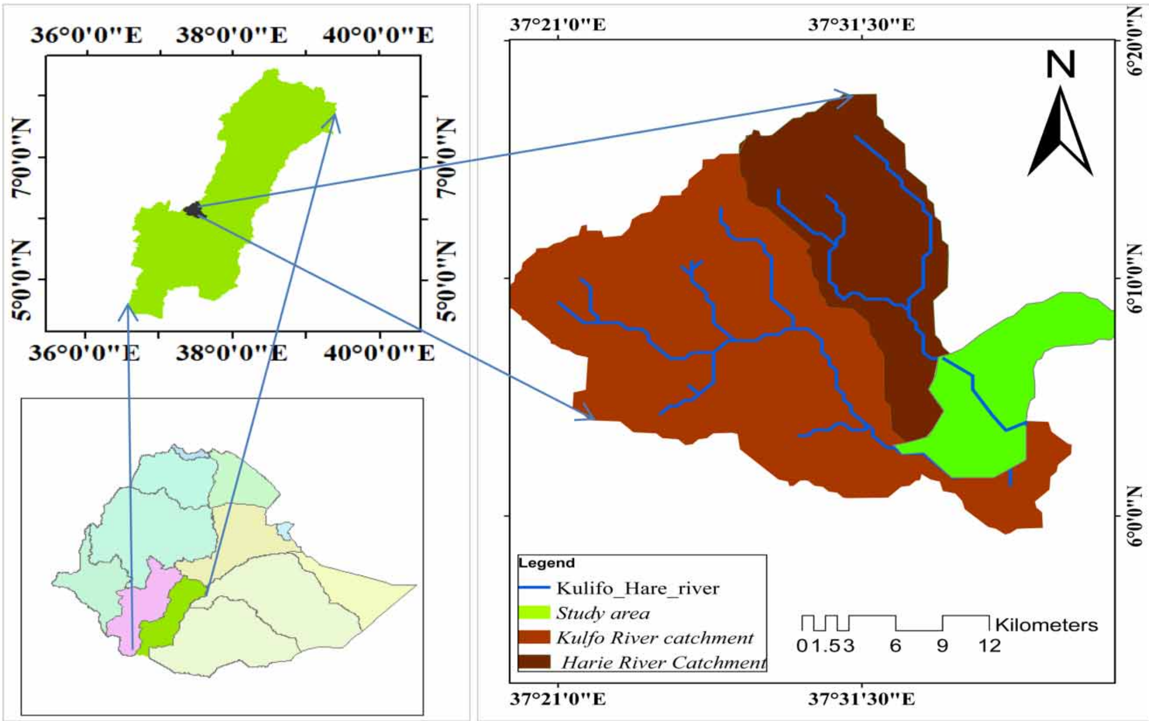


Figure 1 | Location map of the study area.

The climate of the river catchments varies from the semi-arid at low lands of rift valley floor to humid high lands of mountain ranges. The annual mean rainfall in the lowlands is 880 mm and the annual mean rainfall in the highlands is as high as 1,541 mm. Two-season annual rainfall pattern prevails in the study area (March to May and September to November). The mean maximum and minimum annual temperatures in the study area are 34.9 and 30.2 °C, respectively.

The river catchments are covered by Tertiary and Quaternary volcanic rocks. The oldest volcanic rocks (Oligocene to Middle Miocene) are found in the study area. The volcanic rocks are distributed considerably in the highlands and slightly on the rift floor (Corti *et al.* 2013). These volcanic rocks are composed of interstratified ignimbrite beds and basaltic lava flows that have been covered in enormous rhyolites, tuffs, and basalts (Ebinger *et al.* 1993). The dissolution of silicate minerals in the presence of CO_2 resulted in the release of Na^+, K^+, Mg^{2+}, Ca^{2+}, and HCO_3^- to the groundwater and the composition of groundwater is directly related to water–rock interactions in the area. In the research area, therefore, groundwater types are predominantly Ca–Mg–HCO_3 types (Haji *et al.* 2021).

2.2. Water sampling and analysis

Samples of surface drainage water and irrigation water were collected from the four irrigation command areas (Amibira farm, Arbaminch University research farm, Shara and Chano community-managed irrigated farms) during the main rainy season (March to May).

The physical and chemical parameters were analyzed for each sample and used to evaluate drainage water for irrigation reuse based on the international standards of irrigation water quality. The water quality for irrigation was assessed using WQIs. The procedure followed is summarized in the following steps:

Step 1: Designing a water quality monitoring program that covers the investigated command areas (for both surface drainage channels and irrigation canals) for the considered study period.
Step 2: Collecting water samples from drainage channels and irrigation canals during the main rainy season as surface drainage water occurs in command areas only due to unexpected rainfalls after irrigation applications and the in situ measurement of some water quality parameters.
Step 3: Laboratory analysis of physical and chemical water quality parameters (for drainage and irrigation water).
Step 4: Computing the irrigation water quality indices (IWQIs) for water samples (both drainage and irrigation) using standard formulae.
Step 5: Assessing IWQIs for water quality status and suitability for irrigation.

Fifty-seven (57) samples were collected from the whole irrigation command areas (19 samples in three rounds; Figure 2). In the first round of fieldwork, four irrigation water samples were collected from four sites (head of field canals for each of the four irrigation command areas). The total number of irrigation water samples collected was 12 in three rounds from the sample sites at 10-day intervals. Forty-five (45) drainage water samples were collected

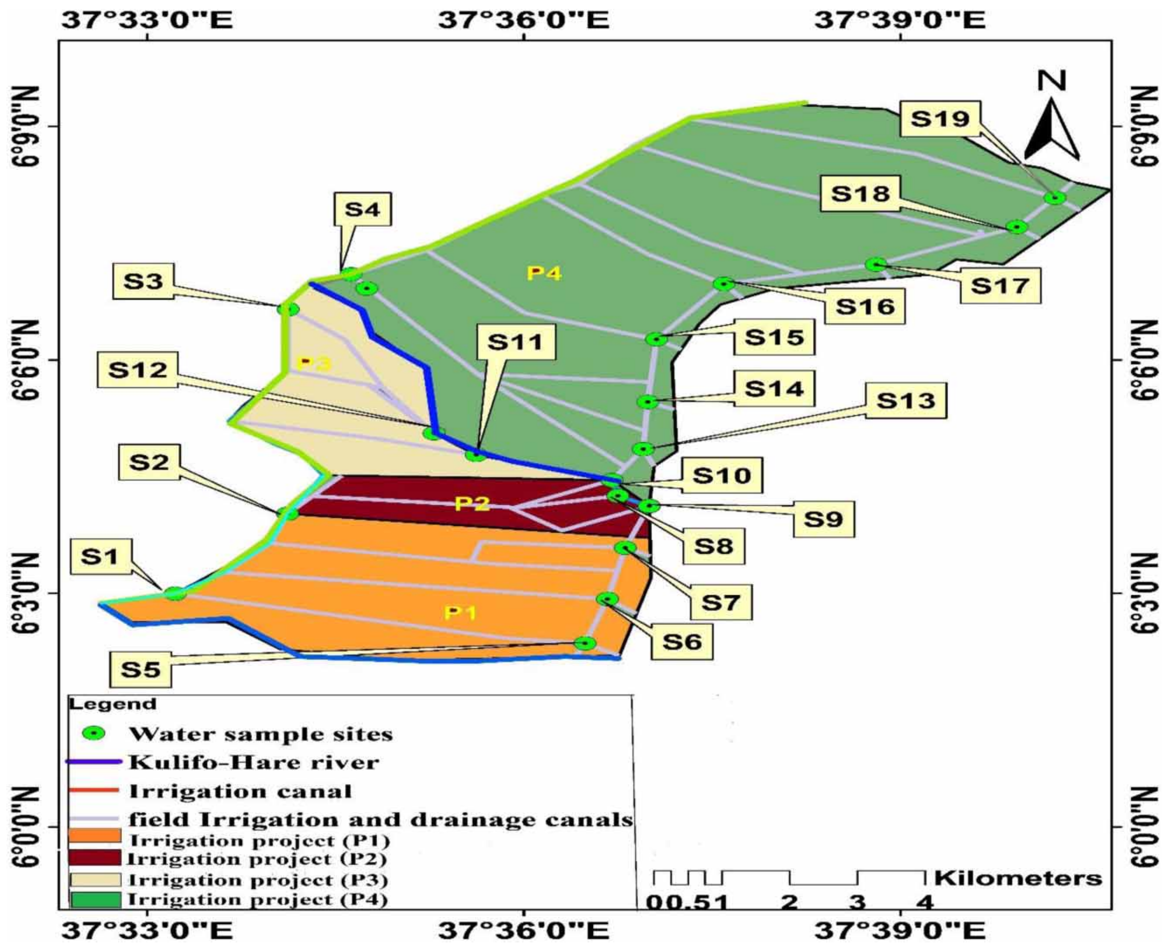


Figure 2 | Water samples collection network (S1, S2, S3, S4 = Irrigation water samples for Amibara, Arba Minch University research center, Shara community, and Chano community irrigation project sites, respectively; from S6 to S19 drainage water samples sites from all irrigation projects).

from 15 sites at the downstream end of the irrigation command areas and the beginning of the drainage channels; three times in 10-day intervals (three sites in the Amibara farm, three sites in the Shara community-managed farm, one site in the Arba Minch University research farm, and eight sites in the Chano community-managed farm). All samples were collected in thoroughly rinsed plastic bottles of 1-liter capacity and kept in a cooling box while transported to the laboratory.

The recorded and analyzed parameters were (1) three physical parameters: water temperature, turbidity, and total dissolved solids (TDS); (2) fourteen chemical parameters: pH, EC, TH, DO, NO_3, PO_4, and major cation ions Na^+, Ca^{2+}, K^+, Mg^{2+}, and major anion ions HCO_3^-, CO_3^{2-}, Cl^-, and SO_4^{2-}. Temperature, turbidity, TDS, PH, EC and DO were analyzed in the field using Aqua meter and the remaining parameters were analysed in laboratory. This was critical to prepare the parameters for the water quality index irrigation laboratory assessment (FAO 1994).

The physicochemical properties of samples were examined using standard analytical procedures. Sulfate concentrations in water samples were determined gravimetrically using a $BaCl_2$ solution, whereas Cl^- concentrations were determined by titration with $AgNO_3$. The titration method was also used to determine carbonates and bicarbonates. The extractable cation concentrations (Na^+ and K^+) were determined using flame photometry (an instrument with the model: PHF 80B Biology Spectrophotometer was used), whereas Ca^{2+} and Mg^{2+} concentrations were determined using an atomic absorption spectrometer (an instrument with model no. 2380 was used).

Furthermore, 15 mL of 1% ammonium pyrrolidine dithiocarbamate and 30 mL of methyl isobutyl ketone were added to each sample. For 15 min, the mixture was vigorously shaken. Following phase separation, the aqueous layer was drawn off into a clean separating funnel and another 30 mL of MIBK was added, while the upper MIBK layer containing the extracted elements was collected in a small 100 mL separating funnel. The same procedure was repeated three times. The extracted 15 mL aqueous layer of 2N HNO_3 containing the chelated metal from the sample solution was kept in tight-stopper scintillating vials for storage until analysis (El-Amier *et al.* 2021).

2.3. IWQI evaluations

Irrigation water quality assessment is essential to prevent the accumulation of salt or the development of alkalinity or acidity and their effects on the soil moisture movement and its extraction by plants from the soil. To measure water quality, the water quality parameters were calculated using the equations shown in Table 1. The suitability of the agricultural drainage water quality for irrigation purposes was evaluated by the IWQIs such as EC, TDS, SAR, Na%, PI, RSC, MAR, KI, PS, and TH.

In the research area, the suitability of the agricultural drainage water quality for irrigation purposes was categorized using the descriptions of different authors (Table 2): The suitability category was evaluated based on IWQI factors, such as EC, TDS, SAR, Na%, PI, RSC, MAR, KI, PS, and TH, and water quality index of irrigation (WQII).

3. RESULTS AND DISCUSSION

3.1. Drainage water physiochemical characteristic

The results of the analysis of physiochemical characteristics of forty-five surface drainage water samples, collected from the drainage channels for four irrigation command areas during the period of the main crop sowing season in 2022, are presented below. The physical and chemical parameters of the drainage water were compared with the international water quality standard for irrigation.

The water samples contained varying amounts of constituents of physical and chemical properties, which are of prime importance in evaluating the quality of water for irrigation (Table 2). The chemical composition of irrigation water is presented in Table 3.

3.2. Drainage water quality suitability assessment

3.2.1. Electrical conductivity (EC)

The average EC of surface drainage water in the study area has the minimum value of 352.49 $\mu S\,cm^{-1}$ at the Shara drainage system and the maximum value of the EC of 685.79 $\mu S\,cm^{-1}$ at the Amibara drainage system (Table 2). The value of EC for irrigation water was 173.72 and 232.30 $\mu S\,cm^{-1}$ for the Kulfo River and the Hare River, respectively. Therefore, according to Adimalla & Venkatayogi (2018), the drainage water quality

Table 1 | Drainage water reuse suitability classification based on irrigation water quality factors and their equation

Irrigation water quality factors	Equations	Values range	Water quality suitability category	Reference
Electrical conductivity (EC) (µS cm^{-1})	Aqua meters reading	<250 250–750 750–2,000 2,000–3,000	Low Medium High Very high	Adimalla & Venkatayogi (2018)
Total dissolved solids (TDS) (mg l^{-1})	Aqua meters reading	<175 175–525 525–1,400 1,400–2,100 >2,100	Excellent Good Permissible Doubtful Unsuitable	Chen *et al.* (2019)
Sodium adsorption ratio (SAR)	$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	<10 10–18 19–26 >26	Excellent Good Fair poor Unsuitable	Richards (1954)
Sodium percentage (Na%)	$Na\% = \left(\frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+}\right) * 100$	<20% 20–40% 40–60% 60–80% >80%	Excellent Good Permissible Doubtful Unsuitable	Wilcox (1955)
Permeability index (PI)	$PI = \left(\frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+}\right) * 100$	>75% 25–75% <25%	Suitable Moderate Unsuitable	Doneen (1964)
Residual sodium carbonate (RSC)	$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$	<1.25 1.25–2.50 >2.50	Good Medium Unsuitable	Richards (1954) and Adimalla & Venkatayogi (2018)
Magnesium adsorption ratio (MAR)	$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100$	<50% >50%	Suitable Unsuitable	Ravikumar *et al.* (2011)
Kelly's index (KI)	$KI = \frac{Na^+}{(Ca^{2+} + Mg^{2+})}$	<1 >1	Suitable Unsuitable	Kelly (1940)
Potential salinity (PS)	$PS = Cl^- + \frac{1}{2} SO_4^{2-}$	<3.0 3.0–5.0 >5.0	Excellent to good Good to injurious Injurious to unsatisfactory	Doneen (1964) and Ravikumar *et al.* (2011)
Total hardness (TH)	$TH = Ca^{2+} + Mg^{2+}$	0-60 61–120 121–180 >181	Soft Moderate Hard Very	Durfor & Becker (1962)
Irrigation water quality index (IWQI)	$Si = \left(\frac{V_{actual} - V_{ideal}}{V_{standard} - V_{ideal}}\right) * 100$ $RWi = \frac{Wi}{\sum_{i=1}^{n} Wi}$ $Wi = \frac{1}{V_{standard}}$ $IWQI = \sum_{i=1}^{n} Si * RWi$	0–25 26–50 51–75 76–100 >100	Excellent Good Poor Very poor Unsuitable	Sener *et al.* (2017)

All ions are expressed in meq l^{-1}.

falls under the 'medium' salinity of drainage water quality classification. Irrigation water sources quality classification stands at 'low' salinity of irrigation water (Table 3).

3.2.2. Permeability index (PI)

The PI for irrigation water quality systems takes into account the soil's Na^+, Ca^{2+}, Mg^{2+}, and HCO_3^- concentrations (Doneen 1964). The drainage water quality demonstrates that the minimum PI value was 25.93% and the maximum value of PI was 42.65% at the drainage channels. The PI value for irrigation water from the Kulfo River was 35.02% and the Hare River was 35.42%. Therefore, based on PI values, all samples of irrigation

Table 2 | Average chemical and physical composition of surface drainage effluent

					Cations (mmolc l^{-1})				Anions (mmolc l^{-1})				
Sampling site	pH	EC (μS cm^{-1})	TDS (mg l^{-1})	DO	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
AmF	7.86	685.79	282.48	0.30	16.44	3.18	6.27	0.11	3.03	3.48	0.32	0.94	0.64
AMURF	7.67	476.72	111.50	0.35	14.05	2.56	7.55	0.35	4.18	3.72	0.33	0.79	0.46
ShCIF	7.75	352.49	96.64	0.41	21.14	1.66	5.92	0.07	2.32	3.72	0.34	0.65	0.35
ChCIF	7.98	566.61	542.65	0.44	14.52	1.63	8.48	0.12	4.09	4.65	0.35	0.45	0.52

Note: AIP1 is Amibara farm; AMURF is Arba Minch University research farm; ShCIF is Shara community irrigation farm; ChCIF is Chano community irrigation farm.

Table 3 | The average chemical and physical composition of irrigation canal water

					Cations (mmolc l^{-1})				Anions (mmolc l^{-1})				
Source of canal water	pH	EC (μS cm^{-1})	TDS (mg l^{-1})	DO	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
KR	7.88	173.72	111.1	3.78	19.66	2.32	8.33	0.17	5.22	3.78	0.39	0.36	0.33
HR	7.32	232.30	166.6	3.11	17.78	2.00	7.55	0.11	4.56	3.44	0.44	0.28	0.28

Note: KR is Kulfo River; HR is Hare River

water sources in this study area were highly suitable and the drainage water was considered to be acceptable for irrigation purposes (Table 4).

Table 4 | Irrigation water quality indices of surface drainage effluent samples

	Irrigation water quality index factors							
Site	SAR	Na%	PI	RSC	MAR	KI	PS	TH
AmF	2.01	25.37	32.44	−15.95	16.66	0.33	3.96	19.61
AMURC	2.62	32.23	39.71	−11.96	15.38	0.45	4.11	16.61
ShCF	1.75	20.81	25.93	−20.13	7.28	0.26	4.04	22.80
ChCF	2.98	34.74	42.65	−11.53	10.07	0.53	4.87	16.14

Note: AmF is Amibara farm; AMURC is Arba Minch University research farm; ShCF is Shara community farm; ChCF is Chano community.

3.2.3. Sodium percentage (Na%)

When sodium and soil interact with each other, the permeability of the soil will be reduced. Sodium concentration in the surface water is expressed in percent, which is also used to identify Na hazards. The Na% of the surface water in the study area has the minimum value of 20.81% at the head of the drainage canal system and the maximum value of Na% was 34.74% at the tail of the drainage canal system (Table 4). The value of Na% is 27.88 and 27.94% for the Kulfo and Hare Rivers, respectively, as sources of irrigation water. Therefore, according to Wilcox (1955), all drainage water samples are good or safe for irrigation (Table 5).

Table 5 | Average irrigation water quality indices of irrigation canal water samples

	Irrigation water quality index factors							
Site	SAR	Na%	PI	RSC	MAR	KI	PS	TH
KR	3.78	27.88	35.02	−16.43	10.56	0.38	3.96	21.99
HR	3.11	27.94	35.45	−14.94	10.11	0.38	3.58	19.78

Note: KR is Kulfo River; HR is Hare River.

3.2.4. Sodium adsorption ratio (SAR)

The SAR of water in the study area has the minimum value of 1.75% at the head of the drainage water system and its maximum value is 2.98% at the head of the drainage water system (Table 4). As a source of irrigation water, the value of SAR is 3.78 and 3.11% for the Kulfo and Hare Rivers water, respectively. Therefore, according to Richards (1954), the sampling sites of the four irrigation command areas fall under 'excellent' (Tables 4 and 5).

3.2.5. Kelly's index (KI)

The Na^+, Ca^{2+}, and Mg^{2+} concentration levels in the water are used to calculate the value of KI as an essential measure in the evaluation of irrigation water quality (Kelly 1940). In this study, the KI of the drainage water in the study area has the minimum value of 0.21 and the maximum value of 0.53 at the head of the drainage water system (Table 4). The value of KI for the Kulfo River and the Harie River is 0.38. As a result, the sampling sites for the command areas have a Kelly value of less than 1 and are classified as 'suitable' (Tables 4 and 5).

3.2.6. Magnesium absorption ratio (MAR)

A high level of MAR (>50%) in a water sample causes soil alkalinity. In this study, the MAR of the water in the study area has the minimum value of 7.28% and the maximum value of 17.81% at the head of the drainage water systems (Table 4). The values of MAR for the Kulfo and Hare Rivers are 10.56 and 10.11%, respectively. Therefore, in the irrigation command areas, all water samples are categorized as less than 50% and this indicates it is suitable for irrigation (Tables 4 and 5).

3.2.7. Potential salinity (PS)

PS is another water quality parameter-based index for classifying irrigation water (Doneen 1964). In this study, the minimum value of PS of the water in the study area is 4.04 and the maximum value is 4.67 at the head of the drainage water system (Table 4). The values of PS in the Kulfo River and the Hare River are 3.96 and 3.58, respectively. Therefore, according to irrigation water quality standards, the irrigation command areas' drainage and irrigation water samples are classified as 'good' to 'injurious' (Tables 4 and 5).

3.2.8. Residual sodium carbonate (RSC)

Water with high $NaCO_3$ concentrations is more likely to precipitate Ca^{2+} and Mg^{2+} in the soil. Irrigation is typically deemed safe when RSC levels are less than 1.25 meq l^{-1}. In this study, all water samples are good or safe for irrigation (Tables 4 and 5) because all samples fall under less than 1.25 meq l^{-1} RSC (Tables 4 and 5).

3.2.9. Total hardness (TH)

Total hardness is the sum of calcium and magnesium ion concentrations. The maximum value of drainage water TH in the study area is 27.35 at the head of the drainage water (Table 4). The value of TH in irrigation water is 21.99 and 19.78 for the Kulfo and Hare Rivers, respectively. All water samples collected in the irrigation command areas are classified as soft water (Table 5).

3.2.10. Irrigation water quality index (IWQI)

The suitability of the drainage water for irrigation reuse was evaluated using the following IWQI factors: EC, TDS, SAR, NA%, PI, RSC, MAR, KI, PS, and TH (Tables 4 and 5).

In this study, the minimum IWQI value in four irrigation command areas is 47.84 in the Harie River irrigation water and the maximum is 84.89 in the Amibara irrigation water (Table 6). Water samples from the drainage water system indicated very poor in the Amibara irrigation command area; poor in the Chano community irrigated farm, and Arba Minch University research farm. Water samples from the drainage system of the Shara community irrigated farm, Kulfo River (KR) and Hare River (HR) are categorized under 'good suitability' (Table 7). Therefore, the drainage water of the irrigation command areas, except the Shara community-irrigated farm, needs treatment before reuse for irrigation purposes.

4. DISCUSSION

The primary effect of high EC irrigation water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). In this study, the minimum value of 352.49 μScm^{-1} of EC was recorded at the Shara community-managed small-scale irrigation command area. Whereas the maximum EC value of 685.79 $\mu S\ cm^{-1}$ was recorded at the Amibara irrigation command area. Therefore, the present

Table 6 | Average irrigation water quality index (IWQI) suitability classification

	Irrigation water quality index suitability classification		
Sampling site	**IWQI**	**Suitability classification**	**Justification**
AmF	78.98	Very poor	Very sensitive/Not suitable
AMURF	62.34	Poor	Sensitive/Slightly suitable
ShCIF	47.88	Good	Tolerant/Moderately suitable
ChCIF	57.90	Poor	Sensitive/Slightly suitable
KR	49.00	Good	Tolerant/Moderately suitable
HR	47.84	Good	Tolerant/Moderately suitable

Table 7 | Water quality index factors suitability for irrigation purposes

	Water quality index factors suitability classification										
Site	**Alkalinity**	**Salinity**	**TDS**	**SAR**	**Na%**	**PI**	**RSC**	**MAR**	**KI**	**PS**	**TH**
AmF	Permissible	Medium	Good	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft
AMURF	Permissible	Medium	Excellent	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft
ShCIF	Permissible	Medium	Excellent	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft
ChCIF	Permissible	Medium	Fair	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft
KR	Permissible	Low	Excellent	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft
HR	Safe	Low	Excellent	Excellent	Good	Moderate	Good	Suitable	Suitable	Good	Soft

findings showed that drainage water quality for irrigation purposes with respect to EC was medium to highly suitable categories across all the sampling locations. This study corroborates the findings of Adimalla & Venkatayogi (2018) who reported that the EC level groundwater in a semi-arid area was not exceeding the normal range. Furthermore, this finding was also supported by different researchers (El-Amier *et al.* 2021).

TDS are a major factor affecting water quality for irrigated agriculture and depend upon minerals and ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, and PO_4^{3-}. Water used for irrigation can vary greatly in quality depending on the type and quantity of dissolved salts. In the present study, the minimum value of TDS was found at the Shara community-managed small-scale irrigation command area to be 96.64.34 mg l^{-1}. Whereas the maximum value of 542.65 mg l^{-1} was found at the Chano community-managed small-scale irrigation command area. Therefore, the result indicates that the category of drainage water quality for irrigation reuse was good to excellent. The water containing TDS less than 525 mg l^{-1} is considered to be in the range of good to excellent water quality category for irrigation. Giri *et al.* (2022) also used TDS to evaluate water quality for irrigation. They reported the extent of salinity hazards could be measured by the ability of water to conduct an electric current since conductance is a strong function of the TDS measurement. Several scholars supported these research procedures (Chen *et al.* 2019).

The PI irrigation water quality system takes into account the soil's Na^{+}, Ca^{2+}, Mg^{2+}, and HCO_3^{-} concentrations (Doneen 1964). In the present study, the PI value of all the locations of the drainage water system ranged from 25.93 to 42.65% and the PI value of irrigation water from the Hare River was 35.02% and it was 35.42% of the Kulfo River water. These findings indicate that both drainage and river water samples fall into the moderately suitable category for irrigation. The study concluded that there might be slightly higher Na^{+}, Ca^{2+}, Mg^{2+}, and HCO_3^{-} at those sites (Doneen 1964). The procedure of the study is also supported by similar studies by Giri *et al.* (2022) and Singh *et al.* (2020) who reported that irrigation water quality in terms of PI level was moderately suitable when the value was 25–33%.

The Na^{+}, Ca^{2+}, and Mg^{2+} levels in the water are used to calculate the value of KI as an essential measure in the evaluation of irrigation water quality (Kelly 1940). In this study, the KI of the drainage water in the study area has the minimum value of 0.26 and the maximum value of 0.53 at the head of the drainage channel. As a result, it indicates that for all samples, Kelly's value was <1 and is classified as 'suitable' for irrigation. This might be due to the dominant levels of Ca^{2+} and Mg^{2+} in all the water samples (Kelly 1940; Alharbi 2018; Giri *et al.* 2022) and they report that the water is suitable based on the KI result of 0.74–0.94.

When sodium and soil interact with each other, the permeability of the soil will be reduced. The sodium concentration in water is expressed in percent, which is also used to identify Na hazards. The Na% of the surface drainage water in the study area has a range value of 20.81–34.74% at the head of the drainage channels. From the head of the irrigation canal (before applied in the command area), the Na% value is 27.88 and 27.94% for the Kulfo and Hare Rivers, respectively, as sources of irrigation water. Therefore, according to the results, all drainage water quality samples were good or safe (Wilcox 1955). This might be due to the lower abundance of Na^{+} in all the water samples. This result supports the findings of the irrigation water quality standard by Giri *et al.* (2022) and Wilcox (1955) who found that the standard of irrigation water ranges from 1.28 to 2.01 and the water is suitable.

The SAR is also related to the Na% in the irrigation water, with a slight difference. The higher level of Na^{+} replaces the Ca^{2+} and Mg^{2+} and the quantity of Na^{+} that is getting adsorbed to the soil is called SAR. A higher SAR would cause a higher reduction in water permeability (Haritash *et al.* 2016). The SAR value of drainage water in the study area ranges from 1.75 to 2.98%. The value of SAR was 3.78 and 3.11% for the Kulfo and Harie Rivers, respectively. Therefore, according to the results, all sample sites of the command areas fall under 'excellent' quality for irrigation (Richards 1954). Giri *et al.* (2022) used SAR levels to categorize water suitability for irrigation and their study supports this by using and following a similar way in this study.

Mg^{2+} is the crucial element that determines water quality for irrigation. Ca^{2+} and Mg^{2+} maintain the cationic equilibrium, but higher Mg^{2+} alters the agricultural yield after releasing Na^{+} from the soil (Ayers & Wescot 1985). In this study, the maximum average MAR level of the drainage water in the study area was 16.66% and the minimum MAR level was 7.28% at the head of the drainage channels. The values of MAR for the Kulfo and Harie Rivers were 10.11 and 10.59%, respectively. Therefore, the surface drainage and irrigation water quality of the command areas are less than 50%, which indicates they are suitable for irrigation. This might be due to the low level of Mg^{2+} in all the collected water samples. The studies reported by Giri *et al.* (2022) and Ayers & Wescot (1985) used MAR level to categorize the source of their irrigation water as not suitable for irrigation purposes.

PS is a Cl^{-}- and SO_4^{2-}-based water quality index for categorizing irrigation water (Doneen 1964). In this study, the PS value of drainage water ranged from 4.04 to 4.87. The PS values of Kulfo and Hare Rivers water are 3.96 and 3.58, respectively. Therefore, according to irrigation water quality standards based on PS, in all irrigation command areas, the surface drainage water and irrigation water samples are classified as 'good' to 'injurious'. This could be due to the slightly lower Cl^{-} and SO_4^{2-} levels in all the water samples. The procedure followed is supported by the studies of Giri *et al.* (2022), El-Amier *et al.* (2021), and Doneen (1964). The lower Cl^{-} and SO_4^{2-} levels indicate water is suitable for irrigation, whereas water with a PS value of >5 indicates not suitable for irrigation purposes.

The comparative study of Ca^{2+}, Mg^{2+} as HCO_3^{-} and CO_3^{-} is described as RSC. A higher level of Ca^{2+} and Mg^{2+} deposition as HCO_3^{-} and CO_3^{-} will increase the Na^{+} level in the soil. Furthermore, an excess amount of CO_3^{-} and HCO_3^{-} to Ca^{2+} and Mg^{2+} may influence the quality of the water for irrigation purposes. The surplus amounts of CO_3^{-} and HCO_3^{-} will mostly interact with Ca^{2+} than Mg^{2+} and this will cause precipitation. Therefore, this will cause the inverse ion exchange process, which ultimately causes sodium hazards (Haritash *et al.* 2016; Singh *et al.* 2020). In this study, all samples are good or safe for irrigation, because they all fall under less than 1.25 meq l^{-1} RSC's. This study was similar to the study by Singh *et al.* (2020), where they used RSC levels to categorize good quality water for irrigation purposes.

5. CONCLUSION AND RECOMMENDATIONS

Assessment of drainage water quality is required to reuse it for irrigation purposes without compromising the soil quality and crop production. The quality of agricultural land drainage water depends on the quality of irrigation water, the chemical and physical properties of soils of the agricultural land, and chemical inputs used for crop production and soil amendments. The suitability of drainage water for irrigation reuse can be evaluated by analyzing the IWQI factors of water samples from drainage effluents. Therefore, in the current study, 19 water sampling sites (4 on irrigation canals and 15 on drainage channels) were strategically selected in four irrigation command areas. The studies conducted on the water samples collected from sampling sites in three rounds with 10-day intervals during the main rainy season showed the following findings.

The study on the water samples from the irrigation canals indicated that the two rivers are safe and permissible with respect to alkalinity and have low salinity and hardness. Moreover, the IWQI factors indicate that the Kulfo and Hare Rivers are good to excellent quality for irrigation.

The results of the analysis of the water samples from surface drainage systems indicated that the drainage water of the Amibara irrigation command area is very poor in terms of IWQI, whereas the drainage water quality of the Chano community-managed small-scale irrigation farm and Arba Minch University research farm are categorized to be poor for irrigation reuse. But the IWQI of water samples from drainage systems of the Shara community-managed small-scale irrigation command area was found to be good for irrigation reuse. Therefore, the surface drainage effluent of the Amibara irrigation command area, Arba Minch University research farm, and Chano community-managed small-scale irrigation command area need treatment before reuse for irrigation purposes.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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