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Evaluation of Irrigation Water Quality of Woyito Irrigation Scheme at Bena Tsemay District in South Ethiopia in South Omo Zone, South Ethiopia

Medhin Madebo, Abebe Hegano and Yenesew Animaw

*South Ethiopia Agricultural Research Institute (SEARI), Jinka Agricultural Research Center (JARC), P.O.Box 96, Jinka, Ethiopia, *Corresponding author's email: medimadebo@gmail.com*

ABSTRACT

Ethiopia's semi-arid agricultural land loses much of its productivity annually as a result of salinization and sodicity. Knowing the quality of irrigation water before using it for irrigation activities is crucial for land use and irrigation water management. This study was carried out to ascertain and categorize the quality of the irrigation water and suggest potential management alternatives in the south Ethiopian district of Bena Tsemay. To ascertain the quality of irrigation water utilized in the study area, a variety of analyses were performed on the collected water samples. These analyses included pH, EC, SAR, RSC, PI, Na%, and measurements of dissolved cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and anions ($SO4^{2-}$, HCO^{3-}, Cl^{-}, NO^{3-}, $PO4^{3-}$, and $CO3^{2-}$). The water under investigation had a pH between 8.05 and 8.48, which was slightly alkaline and ideal for irrigation. The EC was non-saline during the wet season and slightly to moderately saline during the dry season. The salinity of the area was exacerbated by extensive irrigation during dry seasons, which was partially alleviated by rainfall during wet seasons. During the wet season, the SAR was slightly to moderately sodic at 2.55 meq/l and 1.48 meq/l during the dry season, making it good for irrigation. The residual contained from wet to dry season sodium carbonate (0.36 to -1.02), potassium ion (0.1 to 0.31), and sodium ion (2.73 to 2.07) meq/l, respectively. Besides, chloride (0.31meq/l) level was appropriate for irrigation. A classification of slight to moderate pollution was observed in the HCO3 of the water. The results indicated that the concentrations of phosphate (0.32 meq/L), sulfate (0.26 meq/L), and nitrate (0.4 meq/L) in the water were within acceptable limits, making it suitable for irrigation. To address the long-term salinity and sodicity issues in the research area, salinity and sodicity management and control strategies were employed.

Keywords: Irrigation practices, water quality, Woyito irrigation scheme, salinity problem, sodium adsorption ratio

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1. INTRODUCTION

In order to meet the growing food needs of the world's population, irrigation practices are crucial to increase agricultural productivity and production. Rivers and streams are water resources that cross borders and provide water for agriculture. However, irrigated agriculture is only associated with the physical availability of water, while the quality of water for sustainable agricultural production is often disregarded (Molla & Fitsume, 2017). Soil quality, one of the most important subsystems of agricultural land, changes over time owing to changes in the environment or management practices (Hailu, Wogi, & Tamiru, 2020). Salinization is one of the most devastating environmental pressures resulting from improper irrigation management, leading to a significant reduction in cropland productivity and crop quality (Shahbaz & Ashraf, 2013).

Saline regions of Ethiopia, characterized by higher evapotranspiration in relation to precipitation, are located in the Rift Valley, arid, and semi-arid lowlands. Because of the salinity of the soil and water, arid and semi-arid agro-ecologies, which account for around 50% of the country's geographical area, are considered to be marginal conditions for agricultural development. Low annual rainfall and high daytime temperatures in these lowland areas led to high water evaporation and high concentrations of soluble salts (Begizew, 2021).

Salinization is a problem for irrigated agricultural land owing to the improper management of irrigation systems and poor quality of irrigation water. Ethiopia ranked seventh in the world in terms of the proportion of land area affected by salinization (Giday Adhanom, 2019). In the Rift Valley, large-scale irrigation projects were developed without adequate drainage systems to control salinity. This led to a rapid and sharp increase in salinity and soil salinization and eventually to the loss of land suitable for arable farming in these areas (Walche, Haile, Kiflu, & Tsegaye, 2023).

The main causes of soil salinization in the lowland areas of Ethiopia include: poor water management techniques on farms, intensive soil irrigation, use of poor quality water, and lack of adequate drainage infrastructure (Gebremeskel et al., 2018). As salts alter the osmotic link between soil moisture and roots, they are the main cause of crop problems in poor water quality (Machado & Serralheiro, 2017). Irrigation water must not only be free of chemical and biological contaminants but also contain the right amount of salt. Irrigation water with a high salt content inhibits plant growth and alters the permeability, structure, and aeration of the soil (Singh, Mahato, Neogi, & Singh, 2010); Ackah et al., 2011)).

Reduction of turgor pressure, slowing of cell expansion, and damage to chloroplasts are the effects associated with salt-water irrigation which, in turn, affects growth rate and photosynthesis. Crop yield and dry matter accumulation are ultimately affected by these changes. Malash, Flowers, & Ragab, 2005 reported that gradual increase in soil salinity occurs when saline water is constantly used for irrigation. The intricate relationship between soil systems and water is controlled by the chemical exchange process between the two media (Molla & Fitsume, 2017).

Assessing and testing water quality is an important task especially when the water is used for irrigation purposes. The study area, the Woyito irrigation system, is characterized by an arid and semi-arid climate with low rainfall. Therefore, the communities surrounding the irrigation system rely heavily on conventional furrow and flood irrigation techniques. This has led to salinity and sodicity hazards occurring on farms. However, the salinity of irrigation water in the study area was not recorded in the past, making it difficult to develop intervention scenarios. Farmers are not aware of the salinity of irrigation water or the causes of flooding in these areas. The aim of this study is therefore to assess the quality of irrigation water used in the area and provide baseline data for the irrigation system.

2. MATERIALS AND METHODS

2.1. Study Area Description

2.1.1. Location

The study was conducted in the Bena Tsemay District of South Omo Zone, Southern Ethiopia. The research area is situated at 660 meters above sea level at a latitude of 5°18′0″ to 5°31′33″ N and a longitude of 36°52′30″ to 37°5′0″ E (Figure 1). The region is located in the eastern part of the Bena Tsemay District, 82 kilometers from Jinka, 438 kilometers from Hawassa, and 668 kilometers from Addis Abeba. The area is topographically characterized by valleys, wide flatlands, arid terrain, and a meandering river that stretches to the Chew Bahir area.

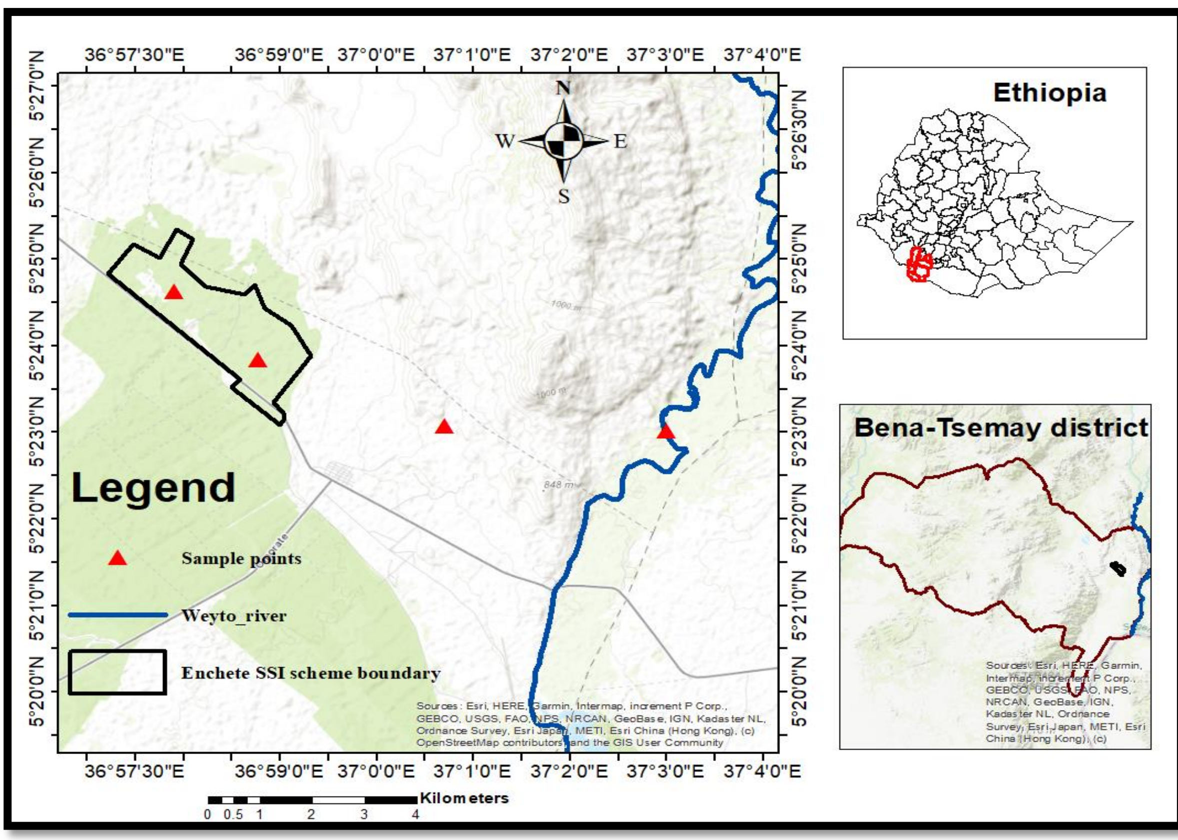

Figure 1: The study area's location map

2.1.2. Climate and Hydrology

The research area had average annual rainfall ranging from 200 to 578 mm and average annual temperature between 25°C and 40°C (Figure 2**: Mean monthly rainfall and temperature of the study area (2022 and 2023)**). The Woyito River served as a source for irrigation. It flows from north to south with its outflow into Chew Bahir Wetlands. Besides, the present study area lies within southern part of the Rift Valley Drainage system (Bezabih Bashe, 2017).

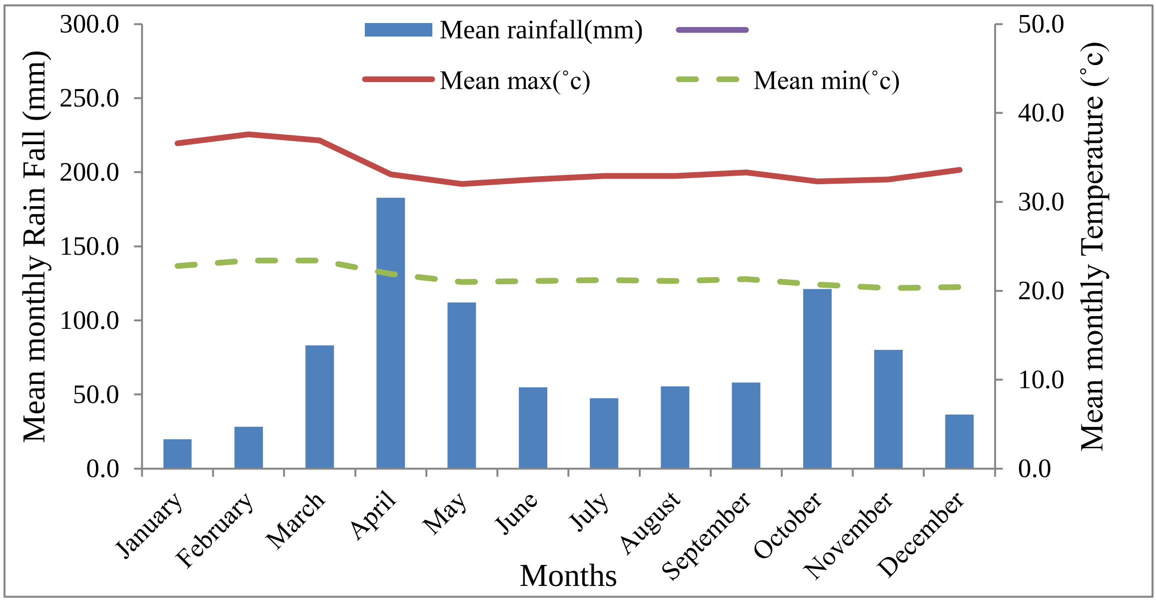

Figure 2: Mean monthly rainfall and temperature of the study area (2022 and 2023)

2.1.3. Land use land cover situation of the area

The Woyito Watershed land use and land cover (LULC) constituted sand, bodies of water, hillsides, bare soils, forests, or other vegetation, dry river beds (DRB), and agricultural land (Bezabih Bashe, 2017). Irrigable agricultural land is the main type of land use that dominates the study area. The soil in the study area was texturally classified as loam soil (Mugoro, Assefa, & Getahun, 2020). The most important irrigated crops of the study area included: cotton, sesame, maize, sorghum, onions, tomatoes, bananas, peppers, watermelon, and sunflowers.

2.2. Water Sampling and Analysis

2.2.1. Site selection

To identify the representative sites, a reconnaissance survey and field observation were conducted in the farm from upstream to downstream along the proposed plan. The sampling locations provided typical water quality; samples along the length of the canal were chosen based on road access to the area being studied. Using purposive sampling method, the sampling sites were chosen from the upper, middle, and lower course of the Woyito irrigation scheme in 2022 during dry and wet seasons.

2.2.2. Sampling technique

In accordance with the requirements of US Salinity Laboratory (McGeorge, 1954), the irrigation water samples were collected and processed. The water samples were collected during the morning hours and subsequently dispatched to the laboratory for analysis within a 24-hour. A one-liter plastic bottle that had been properly washed with distilled water was used to collect irrigation water samples from four typical sites in a single day. The water samples that were taken were promptly sealed to prevent air exposure and subjected to sensitive parameter analysis right away.

2.2.3. Sample collection

In order to test the water quality of the irrigation, representative samples were taken throughout the wet and dry seasons depending on the state of the river flow. Water samples were collected from the upper, middle, and lower irrigation schemes (Enchete and Duma). In order to classify the quality of irrigation water, the collected water samples were analyzed by various parameters in the laboratory of the Arba Minch University Water Technology Institute. Accordingly, the parameters for analyzing irrigation water included: pH, EC, soluble cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), soluble anions ($Cl^{-}$$SO_4^{2-}$, HCO_3^{-}, and CO_3^{2-}).

2.2.4. Laboratory analysis

The pH and EC of irrigation water were measured with a multi-meter devise (Seyedsadr et al., 2022). A flame-photometer was used to measure the soluble Na^{+} and K^{+} (Banerjee &

Prasad, 2020), while an EDTA titrimetric method was used to measure the soluble Ca^{+2} and Mg^{+2} (Barrows & Simpson, 1962) . The volumetric titration method was utilized to determine the total alkalinity as carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) (Verma, 2004). The sulfate (SO_4^{2-}) was examined using a UV-vis spectrophotometer and the turbid metric method (Morais, Rangel, & Souto, 2001). The silver nitrate titrimetric method was used to determine the amount of chloride in the sample (Kolthoff & Kuroda, 1951). Ascorbic acid and disulphonic acid methods were used to determine phosphate and nitrate with a UV-vis spectrophotometer (O, Ruth, Jane, & Charles, 2013). .

The amounts and concentrations of the different chemical properties analyzed were used to compute the SAR, Na%, PI, and RSC of the water samples. , SAR, Na%, and PI are the most fundamental metrics used to assess levels of sodium and associated risks to crops (Chidambaram te al., 2022). Based on measured values of Na^+, K^+, Ca^{2+}, and Mg^{2+}, the following formulas were used to determine sodium adsorption ratio (SAR), sodium percentage (%Na), and permeability index (PI) in the irrigation water. Residual sodium carbonate (RSC) was calculated using concentrations of HCO_3^- and CO_3^{2-} in relation to Ca^{2+} and Mg^{2+}:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}} \quad (1)$$

$$Na\% = \frac{Na^+ + K^+}{Ca^{2+}+Mg^{2+}+Na^+ + K^+} * 100 \quad (2)$$

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+}+Mg^{2+}+Na^+} * 100 \quad (3)$$

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (4)$$

For the concentrations of cations and anions in equations 1- 4, all measurements were expressed in milliequivalents per liter, or meq/L.

The standards outlined in Table 1 were used to assess the water quality suitable for irrigation. The useful suggestions were applied successfully to evaluate common components of water resources in irrigated agriculture. Although the criteria were good to start when identifying restrictions on water quality, they were not sufficient by themselves. Adaptations or solutions to these constraints were also needed (Ayers & Westcot, 1985). Symbols, rules, and laboratory computations and determinations were listed below.

Table 1: Irrigation water quality interpretation guideline from Ayers & Westcott (1985); (Eaton 1950; Wilcox et al. 1954) and Bauder et al., (2011)

Irrigation water quality parameter				Classification		
				None	Slight to Moderate	Severe
EC				< 0.7	0.7 – 3.0	> 3.0
SAR	=	0 – 3	and ECw =	> 0.7	0.7 – 0.2	< 0.2
	=	3 – 6	=	> 1.2	1.2 – 0.3	< 0.3
	=	6 – 12	=	> 1.9	1.9 – 0.5	< 0.5
	=	12 – 20	=	> 2.9	2.9 –1.3	< 1.3
	=	20 – 40	=	> 5.0	5.0 – 2.9	< 2.9
Cl^-(meq/l)				< 4.0	4 – 10	> 10
$NO3^-$(mg/l)				< 5	5 – 30	> 30
$HCO3^-$(meq/l)				< 1.5	1.5 – 8.5	> 8.5
pH				acidic	normal range	Basic
				< 7	6.5 – 8.4	> 7
RSC(meq/l)				Safe	Marginal	Unsuitable
				< 1.25	1.25 – 2.50	> 2.5

2.2.5. Statistical analysis

Water quality data from the Woyito Irrigation Scheme were categorized according to seasonal variations. For each parameter and sampling site, the mean and standard deviation of water quality data were computed.

3. RESULTS AND DISCUSSION

3.1. Characteristic features of irrigation water quality

A chemical composition analysis was conducted on irrigation water samples obtained from the Woito Irrigation Scheme (Tables 2 and 3). The intended use of the water determines its quality. For irrigation water, standard quality requirements include salinity, sodicity, and ion toxicities. The soluble salt concentration in irrigation water is commonly measured regarding electrical conductivity (EC) and pH (Abdurahman, Shure, & Wakshum, 2017).

3.2. The pH of Water Sample

The average pH value of the Woyito Irrigation Scheme ranged between 8.05 and 8.48 during wet and dry seasons (Table 2: **The chemical composition of samples from irrigation water during the wet season** and **Table 3: The chemical composition of sample irrigation water during the dry season** , Figure 3**: Mean seasonal variation of irrigation water quality parameters in the area**). The water samples from the Woyito Irrigation System had a high pH value. According to (Haile, 2019) and (Bauder, Waskorn, & Davis, 2011), this was due to high bicarbonate and carbonate levels. The pH of the Woyito Irrigation water remained within an acceptable range for each season (Aregahegn & Zerihun, 2021). Similarly, water with a pH of 6.0 to 8.5 is often acceptable for irrigation (Armstrong, Cotching, & Bastick, 2001). The pH of irrigation water can be affected by the soil to which it is applied and is therefore not considered an absolute indicator of water quality; furthermore, most crops can tolerate a wide range of pH values (Rengasamy, 2018).

3.3. Salinity (EC) of Irrigation Water

The salt content is a decisive parameter for the quality of irrigation water as it is directly proportional to the amount of salt dissolved in the water. The concentrations of soluble salts in irrigation water can be classified on the basis of the electrical conductivity of the water (ECw). The salinity hazard in irrigation water was classified based on the EC values as indicated in Table 2: **The chemical composition of samples from irrigation water during the wet season** and **Table 3: The chemical composition of sample irrigation water during the dry season** , Figure 3**: Mean seasonal variation of irrigation water quality parameters in the area**. The EC value of irrigation water was classified on the basis of the FAO guidelines (Ayers & Westcot, 1985). EC value of irrigation water in the study area ranged from 0.29 to 0.3 in the wet season with an average of 0.3dS/m. In the dry season, the electrical conductivity (EC) ranged between 1.84 and 1.88 with an average of 1.87dS/m. According to (Ayers &

Westcot, 1985), the EC value of the Woyito Irrigation water was classified as non-saline in the wet season and slightly to moderately saline in the dry season.

The analysis of the water samples revealed seasonal fluctuations in the electrical conductivity of the irrigation water. The lower values observed in the wet season and higher values in the dry season can be attributed to salt leaching caused by rainfall (Lu et al., 2015). In the dry season, irrigation water evaporates due to high evaporation rates, while soluble salts accumulate on the soil surface (Begizew, 2021). According to (Aregahegn & Zerihun, 2021), the concentration of dissolved salts is high in the dry season when the river level decreases, and lowest in the wet season when the water level increases. In arid and semi-arid regions, poor drainage can cause or exacerbate salinization (Yasuor, Yermiyahu, & Ben-Gal, 2020). A very dense soil structure with insufficient water infiltration, inadequate aeration, and increased surface crusting is the result of continuous irrigation with excessively salinized water. This leads to a sodium hazard that hinders seedling emergence and root growth; moreover it makes tillage difficult (Zaman et al., 2018).

3.4. Sodicity (SAR) of Irrigation Water

The sodium content of irrigation water is crucial for assessing its potential hazard and is usually evaluated using the sodium adsorption ratio (SAR). The SAR is an important indicator of sodium hazards to plants and soil structure and helps determine the suitability of the water for irrigation purposes. This hazard is due to the negative effects of salt on the soil. The SAR value of irrigation water is categorized based on the irrigation water quality guidelines listed in **Table 1**. During the wet season, the SAR of irrigation water in the study area ranged from 2.48 to 2.68 with an average of 2.55meq/l as shown in Table 2: **The chemical composition of samples from irrigation water during the wet season** and **Table 3: The chemical composition of sample irrigation water during the dry season** , and on **Figure 3: Mean seasonal variation of irrigation water quality parameters in the area**. In the dry season, the SAR ranged from 1.44 to 1.55 with an average of 1.48meq/l. Hence, the SAR of irrigation water in the study area was suitable for irrigation in the dry season, while it was slightly-moderately suitable for irrigation in the wet season as indicated in **Table 1**. While low-sodium water is safe for irrigation, it can harm plants such as fruit trees and avocados that are sensitive to sodium (Zaman et al., 2018). Gypsum is an important chemical additive used to neutralize the RSC of irrigation water and is the most cost-effective alternative to reduce the sodium content of irrigation water compared to other additives (Chander, Rajender, Yadav, & Chander, 2019).

3.5. Residual Sodium Carbonates (RSC)

The RSC (Residual Sodium Carbonate) value is a measure of the alkalinity of the irrigation water, which consists of HCO_3^- and CO_3^{2-} ions in relation to Ca^{++} and Mg^{++} ions. If there is an excess of carbonates in the irrigation water, the sodium ions dominate as carbonates can form precipitates with calcium and magnesium ions (Nagaraju, Sunil Kumar, & Thejaswi, 2014). The RSC values determined in the wet season ranged between 0.26 and 0.45meq/l with an average value of 0.36meq/l as indicated in Table 2: **The chemical composition of samples from irrigation water during the wet season** and **Table 3: The chemical composition of sample irrigation water during the dry season** . In the dry season, the values ranged from -1.21 to -0.90meq/l with an average value of -1.02meq/l. The analysis showed that the mean RSC value of the water samples from the Woyito Irrigation Scheme was less than 1.25meq/l and was suitable for irrigation (Ayers & Westcot, 1989; Eaton, 1950; Wilcox, Blair, & Bower, 1954).

Table 2: The chemical composition of samples from irrigation water during the wet season

Sampling Point	pH	EC	Soluble Cations (meq/l)				SAR	Soluble anions (meq/l)						RSC	PI	Na%
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		$HCO3^{-}$	$CO3^{2-}$	Cl^{-}	$S04^{2-}$	$PO4^{3-}$	$NO3^{-}$			
S1	8.10	0.30	1.32	0.89	2.61	0.11	2.48	2.39	0.27	0.28	0.26	0.32	0.63	0.45	86.17	55.15
S2	8.10	0.29	1.32	1.01	2.71	0.10	2.51	2.33	0.27	0.31	0.26	0.33	0.21	0.26	83.95	54.58
S3	8.00	0.29	1.36	0.97	2.74	0.09	2.54	2.49	0.27	0.33	0.27	0.28	0.29	0.42	85.10	54.87
S4	8.00	0.30	1.32	0.97	2.87	0.10	2.68	2.37	0.25	0.33	0.25	0.35	0.47	0.33	85.36	56.39
Mean	8.05	0.30	1.33	0.96	2.73	0.10	2.55	2.39	0.26	0.31	0.26	0.32	0.40	0.36	85.15	55.25
Min	8.00	0.29	1.32	0.89	2.61	0.09	2.48	2.33	0.25	0.28	0.25	0.28	0.21	0.26	83.95	54.58
Max	8.10	0.30	1.36	1.01	2.87	0.11	2.68	2.49	0.27	0.33	0.27	0.35	0.63	0.45	86.17	56.39
SD	0.06	0.01	0.02	0.05	0.11	0.01	0.09	0.07	0.01	0.03	0.01	0.03	0.19	0.09	0.92	0.80

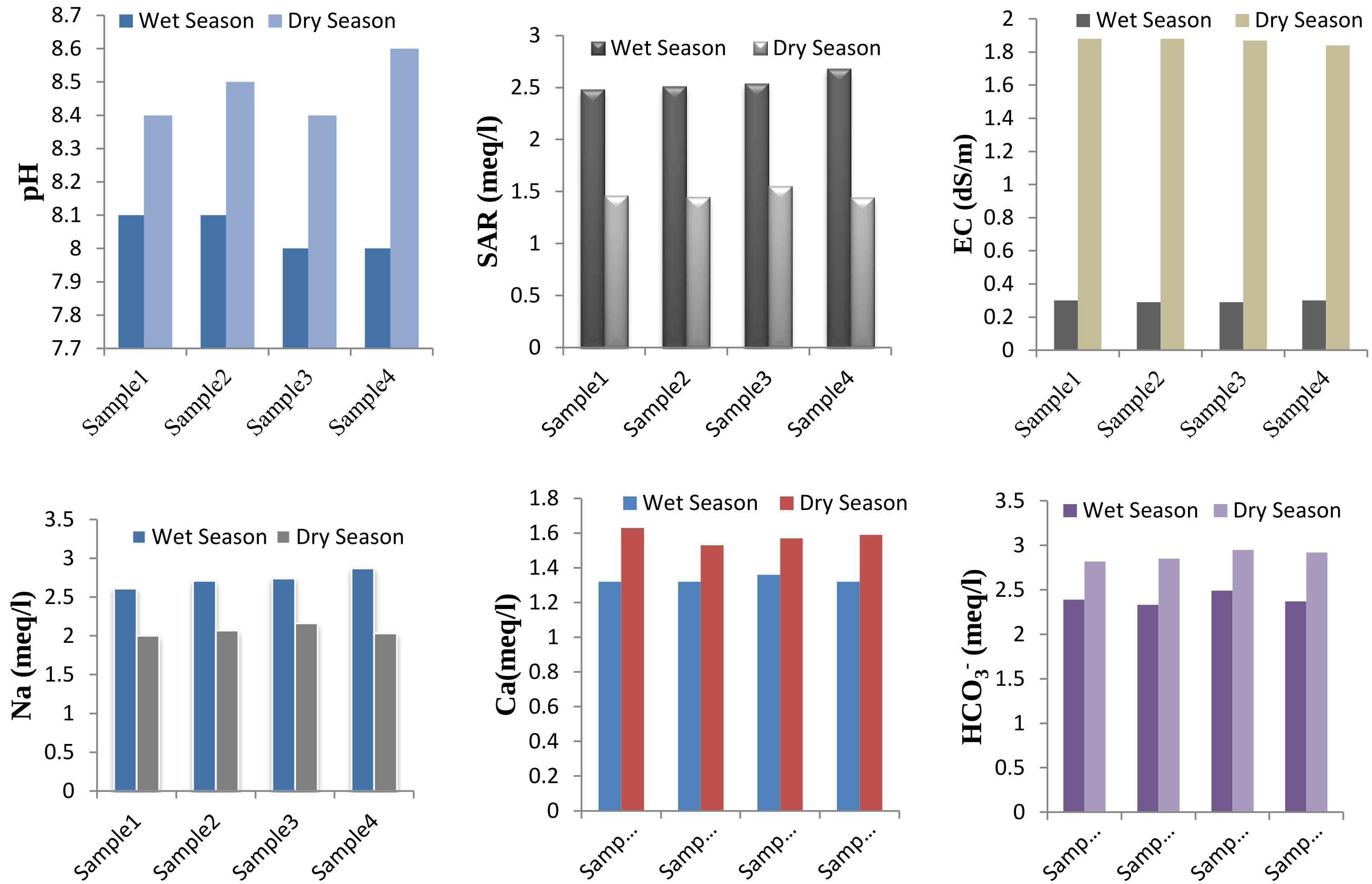

Figure 3: Mean seasonal variation of irrigation water quality parameters in the area

3.6. Concentration of Soluble Cations in Irrigation Water

Higher concentrations of sodium (Na) ions in irrigation water or on agricultural land are particularly concern to the Woyito irrigation scheme users, due to its toxicity to plants and the adverse effects on soil physical properties. Excessive sodium can lead to soil compaction, reduced permeability, and poor aeration, hindering plant growth and crop yield. Sodium toxicity can show up on plants in the form of leaf burns, scorching, and dead tissue on the outer edges of leaves (Simsek & Gunduz, 2007).

The sodium ion value ranged from 2.00 to 2.16meq/l with an average value of 2.07meq/l and 2.61 to 2.87meq/l with an average value of 2.73meq/l in the dry and wet seasons, respectively. The result for Na in (Tables 2 and 3, Figure 3) was less than 20meq/l and the water was suitable for irrigation (Ayers & Westcot, 1985). The potassium ion value ranged from 0.09 to 0.11meq/l with an average value of 0.10meq/l and 0.30 to 0.33meq/l with an average value of 0.31meq/l in the wet and dry seasons, respectively. Therefore, irrigation water with a potassium ion concentration of less than 2 meq/l in Tables 2 and 3 was suitable for irrigation. The variations in Na^{+} and K^{+} concentrations may be related to the geological composition or mineral makeup of the locations.

The calcium ion value ranged from 1.32 to 1.36meq/l with an average value of 1.33meq/l and 1.53 to 1.63meq/l with an average value of 1.58meq/l in the wet and dry seasons, respectively. Hence, the calcium ion concentration in irrigation water as indicated in (Table 2 and **Table 3**, **Figure 3: Mean seasonal variation of irrigation water quality parameters in the area**) was below 20meq/l and was suitable for irrigation. The magnesium ion value ranged from 0.89 to 1.01 meq/l with an average value of 0.96meq/l and 2.13 to 2.53meq/l with an average value of 2.33meq/l in the wet and dry seasons, respectively. As a result, the magnesium ion concentration in irrigation water shown in Tables 2 and 3 was below 5meq/l, which was suitable for irrigation (Ayers & Westcot, 1985). , There was an observed increase in the levels of Ca^{2+} and Mg^{2+}during the dry season. This trend may be attributable to the rapid ingress of rainwater which curtails the dissolution of soil minerals and rocks (Al-Khashman, 2008).

The sodium content (Na %) is an important factor that determines the suitability of irrigation water. A higher concentration of Na^+ leads to chemical bonding with the soil and reduces water movement capacity (Ayers & Westcot, 1985). The values for sodium content (Na %) ranged from 60.77 to 63.08 with a mean of 62.19 in the dry season and from 43.61 to 45.42 with a mean of 44.75 in the wet season. The slight decrease in sodium during the wet season was due to the dilution caused by rainwater; whereas evaporation contributes to ion concentration throughout the dry season (Tlili-Zrelli, Gueddari, & Bouhlila, 2018). The Na% value of irrigation water in the study area was moderately suitable for irrigation in the wet season (Chidambaram et al., 2022). The low quality of irrigation water with Na% value more than 50% was observed in the dry season (Berhanu, Hatiye, & Lohani, 2023).

The permeability index (PI) was used to determine the ability to move water in soil based on the concentration of Ca^{2+}, Mg^{2+}, Na^+ and HCO_3^-. The PI values varied between 83.95 and 86.17 with a mean value of 85.15 in the wet season while the PI value in the dry season ranged between 61.30 and 64.51 with a mean value of 63.03. Seasonal variation of permeability index is mainly related to dilution in the wet season, evaporation throughout the dry season, and agricultural activities (Tlili-Zrelli et al., 2018). The total PI value in both seasons showed a low quality of irrigation water with a PI of more than 60 (Berhanu et al., 2023).

3.7. Concentration of Soluble Anions in Irrigation Water

The most common plant toxicity is caused by chloride ions in irrigation water. Chlorides are necessary for plant growth, but in high concentrations can inhibit plant growth and be highly toxic to sensitive plants, leading to leaf tissue diseases (Simsek & Gunduz, 2007). The chloride ion value was between 0.28 and 0.33meq/l with an average value of 0.31meq/l during the wet season. Hence, irrigation water with a chloride concentration of less than 2meq/l as indicated in Table 2 is safe for all plants (Bhatt et al., 2023; Bauder et al., 2011).

The concentration of bicarbonate ion varied between 2.33 and 2.49meq/l with an average value of 2.39meq/l and between 2.82 and 2.95meq/l with an average value of 2.88meq/l in the wet and dry seasons, respectively. Thus, the concentration of bicarbonate ion in the irrigation water as in Table 2, **Table 3**, and **Figure 3** was between 1.5 and 8.5meq/l. As a result, the irrigation water in the study area was classified as slightly to moderately suitable for irrigation (**Table 1**). The standard deviation (SD) showed that least variability of HCO_3^- in the Woyito Irrigation. However, the HCO_3^- value in the study area did not vary significantly during the study seasons.

The concentration of carbonate ion in the water sample varied between 0.25 and 0.27meq/l with an average value of 0.26meq/l and 0.00meq/l in the wet and dry seasons, respectively (Table 2 and **Table 3**). In general, the concentration of carbonate ion in the irrigation water was below 0.1meq/l in the dry season, which is suitable for irrigation(Ayers & Westcot, 1985). Calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) precipitate insolubly because of carbonate ($CO3_2^-$) and bicarbonate (HCO_3^-) concentration in irrigation water (Zaman et al., 2018).

The nitrogen source refers to the required amount of nitrate used as fertilizer to promote plant growth. The nitrogen source is the required amount of nitrate used as fertilizer for plants. However, excessive amounts can lead to untimely growth or unsightly deposits on the fruits, delayed plant maturity, and yield reduction (Simsek & Gunduz, 2007; Ahmed et al., 2020). These problems were associated with proper fertilization and excellent irrigation management (Shaviv & Mikkelsen, 1993; Simsek & Gunduz, 2007 and Ahmed et al., 2020). The value of nitrate concentration ranged from 0.21 to 0.63 mg/l with an average value of 0.40 mg/l during the wet season. Nitrate content in the area was less than 5 mg/l, indicating that nitrates as fertilizers may be appropriate in certain cases. It is important to exercise caution and use fertilizers responsibly owing to their potential environmental impacts.

The concentration of phosphate ion varied between 0.28 and 0.35 mg/l with an average value of 0.31 mg/l during the wet season. Hence, the phosphate value of irrigation water in the study area was less than 2 mg/l, which was suitable for irrigation (Ayers & Westcot, 1985). The slight seasonal variation observed resulted from the accumulation of phosphates from anthropogenic activities such as agricultural practices and domestic waste discharge which may have harmful impact on the environment. The concentration of sulfate ion varied between 0.25 and 0.27meq/l with an average value of 0.26meq/l during the wet season. Thus, the sulfate value of irrigation water in the study area was below 20meq/l, which is suitable for irrigation (Ayers & Westcot, 1985)

Table 3: The chemical composition of sample irrigation water during the dry season

Sampling Point	pH	EC	Soluble Cations (meq/l)				SAR	Soluble anions (meq/l)		RSC	PI	Na%
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		HCO_3^-	CO_3^{2-}			
S1	8.40	1.88	1.63	2.13	2.00	0.30	1.46	2.82	0.00	-0.94	63.92	38.04
S2	8.50	1.88	1.53	2.53	2.07	0.31	1.45	2.85	0.00	-1.21	61.30	36.92
S3	8.40	1.87	1.57	2.28	2.16	0.33	1.55	2.95	0.00	-0.90	64.51	39.23
S4	8.60	1.84	1.59	2.37	2.03	0.30	1.44	2.92	0.00	-1.04	62.40	37.07
Mean	8.48	1.87	1.58	2.33	2.07	0.31	1.48	2.88	0.00	-1.02	63.03	37.81
Min	8.40	1.84	1.53	2.13	2.00	0.30	1.44	2.82	0.00	-1.21	61.30	36.92
Max	8.60	1.88	1.63	2.53	2.16	0.33	1.55	2.95	0.00	-0.90	64.51	39.23
SD	0.1	0.02	0.04	0.17	0.07	0.01	0.05	0.06	0	0.139	1.456	1.065

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

Irrigation water quality parameters such as pH, EC, SAR, RSC, PI, Na%, dissolved cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+), and anions (SO_4^{2-}, HCO_3^-, Cl^-, NO_3^-, $PO4_3^-$, and CO_3^{2-}) were important measures for the assessment of irrigation water quality in the studied area. The results of the study showed that the pH value of the water samples was below the permissible limit. The EC value of the irrigation water was classified as non-salty in the wet season and slightly-moderately salty in the dry season.

The SAR value of irrigation water affects crop production by increasing the risk of salinity. The SAR was low and suitable in the dry season, while it was moderately suitable in the wet season. However, this resulted in increased soil erosion, lower crop yield, and reduced soil permeability. Therefore, it is important to monitor the quality of irrigation water to minimize adverse effects especially in the wet season.

According to the analysis, the water samples from the Woyito Irrigation System had a mean RSC value of less than 1.25meq/l, indicating that the water was appropriate for irrigation. The water was appropriate for irrigation since the Na ion value was less than 20meq/l and the potassium ion was less than 2meq/l. All plants are safe since the amount of chloride ions in irrigation water was less than 2meq/l. The irrigation water was classified as slightly to moderately suitable for irrigation based on its bicarbonate ion concentration. Besides, the values of nitrate, phosphate, and sulfate were suitable for irrigation. The results from water quality and soil analyses showed that salinity and sodicity were major problems.

4.2. Recommendations

Therefore, to lessen the impact of long-term salinity and sodicity hazard in the study area, proper salinity and sodicity management and control measures should be used. These measures include: adequate drainage, blending low-quality irrigation water with high-quality water, application of mineral amendments, and planting more salt-tolerant crops.

In dry and semi-arid areas, surface irrigation technique such as flood, basin, furrow, and border, were typically exposed to high evaporation rates, which raised the salt concentration in the water. As a result, pipe systems may help to regulate the salinity risks of water resources by substituting open irrigation canals. As a result, more research should be done to ascertain the condition of groundwater quality in the research area.

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