Salinity status on groundwater and impact on irrigated soils: Case of Raya Valley Northern Ethiopia

[1]Mengesha A and *[2]Sahu O
[1]Department of Chemistry, NSC Wollo University (SW) Dessie, Ethiopia
[2]Department of Chemical Engineering, UIE, Chandigarh University, Mohali India

Corresponding author: ops0121@gmail.com

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ABSTRACT

Aim: The main objective of this study was to assess quality of water for irrigation and the impact of associated hazards on soil features and crop yields.
Materials and Methods: A total of 1054 statistical data of primary indices; Total Dissolved Salts (TDS), Electrical Conductivity (EC), sodium adsorption ratio (SAR), Exchangeable sodium percentage (ESP), and specific ion toxicity were collected from perceptible researches publications during 2010 –2020. Salinity, sodicity and specific ion toxicity status of the wells and irrigated soils were evaluated using the guideline specifications of the United Nations Food and Agricultural Organization (FAO).
Results: Most of irrigation scheme in the study area falls within slight to moderate hazard categories. Irrigated soil salinity evaluation showed potential hazards can be expected for sensitive and moderately sensitive irrigated crops and thus, an apt mitigation strategy including selection of tolerant crops is becoming imperative.
Conclusion: It was concluded that outcome may play vital roles in designing efficient irrigation systems and management practices for sound land use and to sustain agricultural productivity.

Keywords: Irrigation Quality Index, Salinity, Sodicity, Toxicity, Salinity Tolerance.

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Introduction

With the rapid rise of global population, there has been a corresponding surged in demand for resources, such as freshwater, food and energy (Raaj et al., 2020). Though over two third of our planet's surface is covered by water, majority of the global water reservoirs are saline or hyper-saline that unfit for municipal, industrial, and agricultural utilization (Sagar and Smruti, 2018). As water is the fundamental material for human needs in various sectors, the demand for water that meet the required quality is increasing dramatically. Moreover, the impacts of extreme weathering events and global climate changes that causes increase in frequency of drought conditions add to the burden of the deficit between demand and supply for fresh water (Tahtouh et al., 2019).

Specially, in arid and semi-arid regions Scarcity of water resources has been a great concern that threatens the sustainability of agricultural crops (Nikolaou et al., 2020). In these arid and semi-arid regions where rainfall and other water sources are not sufficient, groundwater has become the major source of water for the irrigated agriculture as a major source for food supply (Goh et al., 2016). However, the excessive withdrawal of wells and poor irrigation methods are constantly deteriorating irrigated lands as well as the groundwater and thus, this condition is putting pressure on global water demand in an alarming scenario in sustaining agricultural development goals (Roy and Ragunath, 2018).The main issue with the use of groundwater for irrigation is its quality, since the quality of water available to irrigators has significant impacts on nature of soils and crop yields (Ayers and Westcot, 1985). For long-term agricultural productivity, considerate water quality is a critical and necessary condition that enable to design efficient irrigation systems and appropriate crop and soil management practices (Saha et al., 2008).

In Ethiopia, groundwater-based, large-scale irrigation projects are implemented in the Rift valley sites where considerable area of land is becoming unproductive every year because of salinity and sodicity (Giday, 2019). The development of irrigation water demand in the absence of proper drainage systems for salinity control has resulted in increasing severity and rapid expansion of soil salinity and sodicity problems leading to complete loss of land for crop cultivation in these areas (Gebrerufael et al., 2019). The Raya valley, which is part of the Ethiopian Rift Valley, faces the most severe water scarcity problem and is exploiting groundwater for irrigation. Geographically, the area is highly venerable to climate changes and fluctuating precipitation. However, the Ray valleys possess immense groundwater and fertile arable lands. The development of irrigation systems and utilization of groundwater based irrigation in the area is reported by different researchers from governmental and non-governmental institutions. Contrary to the potential resources, the study area is still known as one of the food insecure areas (Hagos and Birhane, 2019). One possible reason behind this is the suitability of groundwater for irrigation and poor irrigation methods that lacks salinity drainage facility. A growing salinity status of the groundwater over time and some degree of salinity hazards in irrigated soils have been reported by different researchers. Moreover, the improper pumping rates and poor irrigation methods that increase groundwater salinity and deterioration of soil fertility of the study area have been reported (Abdella, 2011). The clogging of tubes in drip irrigation system, which indicates the presence of scarcely soluble salt ions such as carbonate, Calcium, and magnesium irrigation water, has been also observed. This issue was raised by Kobo-Girana Valley Development Program Officers (KGVDPO) and trying to introduce perennial crops, such as mango, to mitigate the problem (Shimelis and Teshome, 2015).

However, in literature there is no well-organized information that provide clear and sufficient information on the highly interlinked, poor grade irrigation water quality , irrigation induced hazards , and the associated impacts on irrigated agricultural yields. Consequently, proper mitigation and controlling strategies that needs a critical diagnostic analysis of irrigated soil quality and tolerance capacity/sensitivity/of the local crops for irrigation induced environmental hazard has been ignored (Ayenew et al., 2013, Fenta et al., 2015 and Kahsay et al., 2019).

The purposes of the study were investigation of the existing groundwater quality and the actual status of irrigated soils features using standard irrigation index such as total dissolved salt (TDS) Electrical conductivity(EC) , Sodium Absorption Ratio (SAR) , Exchangeable Sodium percentage (ESP) and concentration of specific toxic ions (Cl^- , Na^+, and HCO_3^-). After statistical analysis; the mean values of these primary irrigation indices were compared with the FAO guideline specifications to achieve the following specific objectives: To evaluate the actual salinity, sodicity, and specific ion toxicity statuses of irrigation water; Characterization of groundwater quality in terms of standard irrigation hazards categories; To examine the existing status of irrigated soils; Impacts of irrigation induced hazards on yields in relation to the tolerance capacity of most local crops in the study area.

Materials and Methods

Overall approach: The general objectives of this study focus on investigation of the existing groundwater quality for irrigation and associated hazards in soil features and impacts on yields of the most local crops for the Raya valley. For this purpose, the data related to groundwater quality and irrigated soils have been collected from prominent research findings published during 2010 to 2020. An irrigation index that combines the overall quality parameters and helps to turn complex statistical data into understandable and useable information have been selected as evaluation tool (Qureshi et al., 2019). Salinity, sodicity and specific ion toxicity status of the wells and irrigated soils were evaluated using the standards guideline specifications of the United Nations Food and Agricultural Organization (FAO).

Based on these standards parameters, namely Total Dissolved Salts (TDS), Electrical Conductivity (EC) ,sodium absorption ratio (SAR) , Exchangeable Sodium Percentage (ESP), and concentration toxic ions (Na^+, Cl^-&HCO_3^-) are considered to evaluate the quality of irrigation water and irrigated soils as well as impacts of salinity on crop yields(Meaza et al., 2017).

A total of 1054 data for all these primary irrigation indices have been collected for statistical analysis. The mean values of the primary index parameters and their total average values are compared with standard irrigation index set by FAO to answer the hypothesis and complete the objectives. The salinity, sodicity and ion toxicity statues of groundwater and irrigated soils have been evaluated using worldwide standard criteria. For all these parameters, a class categorization criterion is used to assess the quality of irrigation and associated irrigation hazard into three degree of hazards and restriction on use classes; None, Slight to moderate and sever. The classification criteria for all these parameters were presented (Table 1). The impact of soil salinity and sodicity hazards on agricultural yields have been examined in relation with the tolerance capacities /sensitivity/ of the most common local crops for area.

The study area: The Raya valley, which embraces about 3808 Km^2 of total area, is found in northern Ethiopia (Fig.1), at about 570 Km from the capital city Addis Ababa. Though it is well known for its fertile arable land resources , the valley experience low and erratic rainfall distribution, which often fail to satisfy the moisture condition for growing crops (Hailu et al., 2019). The ministry of water resources investigated huge groundwater potential of the area that enables to address the food insecurity problems of the society**.** In Raya valley, groundwater- based irrigation projects have been implemented since was 1999 with the aim of enhancing the food security through irrigation development in the valley [30]. Administratively; the valley is divided into parts; Raya-Azebo and Raya- Kobo with respective 2369 km^2 and 1439 km^2 areal converges. The Kobo sub-basin of Valley is found in Northern Wollo Zone of the Amhara National Regional State, whereas, the Azebo part is found in Southern Zone of the Tigray National Regional State, which in north direction of Kobo sub-basin. In both sub-basins of the valley, a number of wells were drilled and irrigation structures have been assembled by the Ministry of Water Resources of the country for utilization of the potential groundwater resource in area (Gebremeskel et al., 2018).

From geologically point of view, the area is considered as part of interconnected valleys of the Ethiopian rift system which is characterized by a series of volcanic rocks and deeply affected by alkaline (olivine) (Adhanom, 2019).

Soil texture: The texture of soil in the Raya Valley is dominantly Salty- loam and clay- loam with deep black that have high water and nutrient holding capacity. The geographically, the Raya Valley is flat plan with deep the soil profile that makes the area highly suitable for irrigation and potential for agricultural development goal. As the commune is mainly dependent on agricultural production, most of the land is intensively cultivated by individual investors and local farmers. Though, Sorghum, Teff and maize were most common crops for in the area , some farmers are getting benefited by cultivating with high-yielding cash crops such as onion, tomato, pepper, vegetables, and grapes for commercial purposes using complimentary irrigation system. The valley is found semi-arid region; its mean annual temperature is about 29°C and the average annual rainfall is 660 mm which is unevenly distributed and erratic. The fluctuations in the weather conditions and frequent appearance of drought in these valley add pressure on farmers who receive less water from rain. Number of boreholes are drilled, pump systems and irrigation infrastructure are installed for pressurized irrigation. Furrow, drip, sprinkler and the traditional surface canal irrigation methods have been used in various sites of the area (Aredehey et al., 2018).

As it reduces weeds, labor demands for weed and preferred by farmers drip irrigation is dominantly utilized in Kobo parts of the Raya valley. Basically, in arid-semi and arid regions, drip irrigation is the most preferred method to save water. The precipitation of salts in water that causes clogging of tubes of the drip irrigation systems is a major problem. However , the traditional flood irrigation method that lack proper design works have been dominantly used for more than 22 years and could led into an adverse irrigation induced hazards that deteriorates soil characteristics and associated crop qualities and yield declines in the valley areas (Zhangzhong et al., 2018)

Irrigation index: The suitability of groundwater for irrigation purpose is evaluated with potential irrigation problems that have significant impacts on nature of soils and crop yields. In this section, primary irrigation indices that reflect the specific features of the irrigation water quality and impacts of associated hazards on irrigated farmlands as well as on crop yields have been described in terms of salinity, sodicity, specific ion toxicity and mixed risks.

Salinity hazard: Naturally, groundwater contains several types dissolved salt ions originated from weathering or dissolution of soil and rocks [32]. The suitability of water for irrigation depends on its total soluble salts contents and the type of plant and soil to be irrigated. The most commonly known salt ions that pose salinity hazards include major cations: sodium(Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) and major anions: chloride (Cl^-) and bicarbonate (HCO_3^-). When the brackish groundwater applied for irrigation these ions get accumulated in the plants' root zone and increase osmotic pressure of the soil moisture that reduces water availability for the crop to the extent that it is suffering from water stress while the soil is wet or moisten. The severity of the osmotic effect may vary with the plants growth stage and in some cases may go unnoticed because of a uniform yield decline over the whole crop. In recent years, the increase in salinity level of water source and their utilization for irrigation purpose is becoming a matter of worry. According to the water quality guidelines, salinity hazard is expressed in terms of the concentrations of total dissolved salts (TDS) and electrical conductivity (EC) (Rawat et al., 2018).

Total dissolved salts (TDS): Total dissolved salts concentration of major cations and anions in irrigation water, is measured in parts per million (ppm) or in the equivalent units of milligrams per liter (mg/L) (Yigzaw et al., 2019).

Electric conductivity: Electric conductivity of irrigation water (ECw) or saturated soil extract (ECe) is usually measured at a standard temperature 25°C and reported in unit of deci - Siemens per meter (ds /m). ECe is a measures the electrical conductivity all the soluble salts in soil water, which is taken from the root zone of irrigated soil samples. According the to the guidelines for interpretation of water quality and salinity hazards; a given test sample can be classified none-saline , slight to moderate saline, and severely saline for its TDS (ppm) and ECW (ds /m) values ranges TDS < 450 or ECw< 0 .7, 450 < TDS< 2000 or 0.7 <ECw< 3 , and TDS > 2000 or ECw> 3, respectively.

Sodicity (Sodium hazards): Sodicity, which refers to relative concentration of Na^+ to that Ca^{2+} and Mg^{2+}, is of special concern for irrigation water quality. Utilization of groundwater with disproportionately high sodium for irrigation results in accumulation of Na^+ in soil. The concentrated sodium ion reacts with the soil particles and removes Ca^{2+} and Mg^{2+} through a base-exchange reaction that impairs soil structure and adversely affects soil productivity .As Na^+ strongly attaches to soil particles it has a cementing effect that reduces soil permeability. Thus sodicity disturbs the air and water balance between soil particles which is essential for healthy growth of plants. Exacerbated sodicity results in soil water logging that obstructs plant's growth. Thus, sodicity had an adverse impact on soil structure and productivity or it declines agricultural crop yields. The Potential sodium hazard is evaluated in terms of irrigation index parameters of Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR). The ESP and SAR of a test sample can be calculated using Equation (1)& (2) and its sodicity status is evaluated by comparing these parameters with standard irrigation catalogues (Dinka, 2016).

$$\text{ESP }(\%) = \frac{[\text{Na}^+]}{\Sigma([\text{Na}^+]+[\text{Ca}^{2+}]+[\text{Mg}^{2+}]+[\text{K}^+])} \times 100 \quad (1)$$

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}])}{2}}} \quad (2)$$

Where: $[Na^+]$, $[Ca^{2+}]$, $[Mg^{2+}]$, and $[K^+]$ are concentrations of the respective cations expressed in milli equivalents per liter (meq/L). According the standard irrigation guidelines, a given test soil sample is termed sodic, when the calculated values SAR≥ 13 or the ESP ≥ 15% if (USSL Staff 195).

These primary irrigation indices that have been identified and specified by the Food and Agriculture Organization of the United Nations (FAO) as evaluation tool for water quality and irrigation induced hazards is summarized in (Table 1). In addition to salinity and sodium hazards, toxicity status of specific ions that cause injuries to sensitive crops such as Cl^- and Na^+ are included in the irrigation index. At lower concentrations these ions are essential for plants but, when a specific ion at a given concentration is taken with irrigation water, it will be buildup in the soil until it reaches a toxic level for crops. A moderate to high concentrations of toxic ions in irrigation water can cause severe leaf burn and complicates soil salinity hazards (Meaza et al., 2019).

Data collection and Statistics Analysis: In this section basic irrigation index data of the irrigation schemes in Raya valley have been collected from noticeable research publications during 2010 to 2020, and compiled for statistical analysis .The primary irrigation parametric data : salinity (TDS & EC), Sodicity (SAR & ESP), and toxic ion contents of boreholes waters and the irrigated soils samples in the study area are summarized (Tables 2**)** and (Table 3). These principal parametric data together with irrigation index (Table 1) will be used to evaluate groundwater quality and irrigated soils of the Raya valley as well as the impact of irrigation induced hazards on crop yields (Kawo and Karuppannan, 2018).

Electrical conductivity of water (EC_W) in deci Siemen per meters (dS/ m), Sodium Absorption Ratio (SAR) and exchangeable sodium percentage (ESP) are dimness and concentrations of Total dissolved salt (TDS), Na^+, Cl^- and HCO_3^- in parts per million (ppm).

Table 1: Guidelines for the evaluation of irrigation water quality

Potential irrigation problems	Parameter	Unit	Hazards and degree of restriction on use: None	Slight to moderate	Sever
1. Salinity	TDS	ppm	< 450	450- 2000	>2000
Affects crop water availability	ECw	dS/m	< 25	0.25 – 2.25	>2.25
2. Sodicity :	SAR	-	10-18	18 - 26	>26
Water infiltration rate	ESP	-	<15	15 -40	>40
3. Ion toxicity :Plant injuryLeaf burn ,scorch affects	Na^+	ppm	< 69	69–207	>207
	Cl^-	ppm	< 70	70–350	>350
4. Miscellaneous Ionic imbalance and toxicity	HCO_3^-	ppm	<92	92–518	>518

Table 2: Descriptive statistics of groundwater quality in Raya valley for year 2010 – 2020 (Mean values Primary irrigation indices (Mean values$\pm SDV$)).

	Salinity		Sodicity		Specific ion toxicity		
#Sample	*TDS*	ECw	SAR	ESP	Na^+	Cl^-	HCO_3^-
33	485 ±450	0.74±0.6	1.52±1.4	28.52±14	58.58±8.2	29.71±7.6	368.46±170
119	583 ±304	0.75±0.36	1.05±0.6	32.15±10	43±1.4	-	368±140
13	1360 ± 737	2.1±1.3	1.3±0.75	13.6±4	63.8±1.3	295.41±67	341.92±150
15	514 ±1209	0.81±1.7	3.83±2.1	24.8±5	72±52	50±14	391±62
10	1244.04±182	0.36±0.11	4.93±1.5	55±15	213.44±24	261.1±28	627.1±17
15	695.33±281	0.23±0.1	1.42±1.54	17.1±6	52.42±2.5	119±31	455.21±19
Six year Ave	813.65±379	0.83 ±**0.7**	2.34±1.6	28.53±**15**	83.9±69	151 ±116	425.3±113

Table 3: Salinity, Sodicity and ion toxicity Status of irrigated soils (0 - 15 cm depth)

Sources		Salinity	Sodicity		Toxicity (ppm)		
# samples	Years	ECe	SAR	ESP	Na^+	HCO_3^-	Cl^-
717	2018	1.91	3.19	47.9	115.5	217.16	213.5
12	2019	0.64	2.4	23.9	147.43	-	-
12	2019	4.74	11.14	14.81	416.67	9.61	16.89
42	2020	2.17	2	2.583	168.13	9.15	4.9
	Min	0.07	2	2.58	115.46	9.15	4.9
	Max	4.74	11.14	47.90	416.78	217.16	213.5
849	Avg.$\pm SDV$	2.22±**1.92**	4.86±**4.1**	22.3±**18.9**	211.92±**133**	60±**100**	59±**9.8**

Results and Discussion

Characterization of Irrigation Water Quality in the Study area: The main irrigation index contents of groundwater at the Raya Valley (mention in Table 2) that have been collected from noticeable research finds were subjected for statistical analysis. The mean values of the 6-year descriptive statistics were evaluated with standard irrigation water quality guideline and categorized under the potential irrigation induced hazard classes (Table 4).

Analysis of Salinity hazard Salinity, which is the most important criterion for evaluating irrigation water quality, is measured by its Electrical Conductivity (EC_W) in deci Siemens per meter (dS / m), or by the Total Dissolved Salt (TDS) concentration in mg /L or parts per million (ppm) (Bradd et al., 1997). The 6-year statistics (Tables 2) revealed that the mean values of TDS ranges from 485 ppm to 1360.52 ppm with an average value of 813.65ppm. In all mean values of the individual year studies as well as total average TDS content of groundwater in Raya valley falls within 450–2000 ppm. When the mean electrical conductivity ($EC_{w)}$ is taken into consideration, it varies from 0.23 to 2.1dS /m and averaging these values for present study gives 0.832 dS /m. Based on the proposed irrigation water quality guidelines the average values of both salinity parameters, (TDS = 813.65ppm and EC_w = 0.832 dS/m) indicate that the salinity status of irrigation water in the study area falls in slightly to moderate salinity hazard class (Table 4) that can reduces moisture availability to the crops, and affect the growth of several moderately sensitive crops and thus yield of farmlands. Moreover, as the concentration of soluble salts in irrigation water concentrate approximately three times in the irrigated soils, the salinity status of irrigation water could lead to soil salinity hazard and physiological drought conditions for in crops (Huang et al., 2016 and Nishanthiny et al., 2010).

Sodicity Hazard class (SAR and ESP): When potential sodicity hazard is taken into consideration, the mean values of SAR and ESP in borehole water samples were reported to vary from 1.05 to 4.93 and 13.6% to 55 %, respectively. The average value of SAR for 6- years was found to be 2.34 which is below permissible limit of irrigation water quality standard. As (Table1 2), majority of wells in Raya valley fall under excellent and good category with regard to SAR that pose no threat to crops and therefore will not have physical problems associated with dispersed clay of the irrigated soil. However, According to Guidelines for assessment of sodium hazard of irrigation water using ECw and SAR together; average of Values of both SAR and ECw (ECw = 0.83 & SAR = 2.34) are in the ranges of 0–3 and 0.2–0.7dS/m , respectively, which indicates borehole waters in the Raya Valley falls in Slight to Moderate degree of restriction on irrigation uses (Williams et al., 1997). Moreover, according to individual year statistics there is fluctuation of SAR values and same wells have higher exchangeable sodium percentage ESP that highlights presence of slight to moderate sodium hazard in groundwater samples of the study area, there is a higher sodium hazard leading to reduced permeability of soils The average value of ESP for 6- year's statistics was found to be 28.53 which is the same as mean value of the2010 research finding (28.52%). According to the standard irrigation index criteria and crops/plants tolerance levels, average value of ESP 28.53 fall within 15 –40 %, which is the permissible limit standard for semi-tolerant crops (Moore et al., 2018). This indicates that Raya valley groundwater may have detrimental effects on sensitive crops such as beans, maize and orange, and slight to moderate impacts on semi-tolerant crops (sorghum, carrot, onion, and tomato). Moreover, from individual year statistics the mean values of ESP in 2013 (55) which is above the permissible limit for tolerant plants include barley, alfalfa ,Rhoades grass like Teff and , grass. Thus, most of wells in Raya Valley fall in slight to moderate sodicity hazard ranges with regard to ESP values that can lead to sever sodic soil conditions (Mirlas, 2012) .

Specific ions toxicity and miscellaneous effects of irrigation water: From the 6-year individual year statistics and the total average value of the Na^+ , Cl^+ and HCO_3^- concentrations (Tables 1, 3 &4) in groundwater borehole water samples falls within slight to moderate degree of restriction on use (Bozdag, 2015). According to guidelines for assessment of specific ions toxicity and miscellaneous effects on common crops most of the borehole water samples falls within slight to moderate degree of restriction on Use, that may lead to significant yields reduction for main crops grown in the Raya valley area. The toxicity occurs due to excessive quantities of sodium and chloride from the irrigation water being absorbed through plant leaves. Extreme damage may include severe leaf burn and defoliation. For surface irrigation, most tree crops (Maize and woody plants are sensitive to sodium and chloride (Muthanna, 2011).

Sodium ions toxicity: mean vales of Na^+ concentration of in borehole water samples varied from 43 to 213.44 ppm with 6 –year's average value 83.87ppm which is within 46 – 230 ppm index class. Concentration of Na^+ in irrigation water is high enough to causes leaf burn, leaf scorch and dead tissues running along the outside edges of leaves and may lead to potential yield reduction for slightly to moderate tolerant crops grown in Raya valley like Tomato ,corn and pepper (Bozdag, 2015).

Chloride Toxicity: Mean values of chloride ion (Cl^-) concentrations in borehole water samples were reported to vary from 29.71 to 295.41ppm with average of 151.044 PPm. From the 5-year Statistics (Table3) together irrigation index (Table 1), the mean of chlorides (Cl^-) concentration (151.04 PPm) falls in slight to moderate ion toxicity class (within 70–350 ppm). This indicates that level of chloride in major of borehole water samples is high enough to inhibit the growth of some sensitive plants. If these borehole waters are used for continual irrigation the excesses chloride ion will deposit on leaves causing a foliar burn and inhibit crops growth by reducing phosphorus availability (Khalaf and Hassan, 2013). However, it is possible minimize the damage caused by high-chloride irrigation water by planting a less sensitive crop or avoiding foliar contact by drip irrigation. Thus, the groundwater in the Raya valley can be utilized to cultivate tolerant crops like cereal (Corns) without yield losses (Saleh, 2016).

Miscellaneous Effects: The mean vales of bicarbonate (HCO_3^-) concentrations in borehole water samples varied from 341.9 to 627. 1 ppm with average 425.28ppm.In general, the bicarbonate concentrations values of below 90 mg/ L are considered to be ideal for irrigation. Mean values of each individual year statistic as well as the total average of the bicarbonate (HCO_3) concentrations are in the range of 92 – 519ppm, which implies that use groundwater for irrigation causes slightly to moderate potential irrigation Problem (Al-Mussawi, 2014).

Evaluation and Characterization of irrigated soil status: In this section , the salinity, sodicity and specific ion toxicity status of the surface soils (in depths of the plant's root zone) are evaluated using standard criteria.

As (Tables 3&6), the mean values of ECe and ESP in surface soils taken from irrigated lands of the Raya valley were found to be in the ranges of 0.43 to 4.4dS/m and 17 to 47.9 %. The with the 5-years average values of the ECe at 25°C (2.22< 4dS/m).According to the propose irrigation index guidelines, all irrigated soils samples in Raya valley falls within slight to moderate salinity hazard categories (Alexander and Mahalingam, 2011).

Soil Salinity analysis: Soil salinity is a measure of the concentration of all the soluble salts in soil water, and is usually expressed as electrical conductivity of saturated extract (ECe). Electrical conductivity of the soil saturation extract (ECe) that has relationship with plant growth, is the standard measure of salinity. Based on the most widely accepted definition of a soil is said to be saline, when its ECe at 25 ^{0}C exceeds 4dS /m. Saline soils contain higher concentrations of soluble salts in the root-zone which is high enough to impair the growth of crop plants. In the case of the Raya Valley irrigated farmlands, the mean values ECein all irrigated soils samples were found to be in the range of 0.43 to 4.4 with 5-years average 2.22 dS/m. Based on the proposed guideline salinity statues of irrigated soils falls within slight to moderate hazard categories, which means, salinity is high enough to cause yield loss for Sensitive (S) and moderately sensitive (MS) crops (Table 7). As the roots of such crops are unable to absorb water from the concentrated soil solution they may wilt despite the availability of adequate moisture (Abdullah et al., 2019).

Soil sodium hazard Analysis: A given soil sample is termed sodic whenever its SAR ≥ 13 or ESP ≥ 15. As shown in Table 6, the mean values of SAR in irrigated soils of the Raya Valley was found to be in range of 2 and 13.61 and that of ESP 17.5 to 47.9 %. Taking the 5-years average for the present study values SAR and ESP were found to be 4.9 and 22.3, respectively. Based on the outcome most of exhibit sodic nature implies that ESP tend to de-flocculate soil aggregates and, hence, lower their permeability to water (Metternicht and Zinck, 2003). According to the US Salinity Laboratory Staff [USSLS] (1954) criteria for classification , the 5-years average values of the ECe at 25°C (2.22 < 4 dS/m , and that of the ESP = 22.3 > 15% which implies that the physiochemical characteristic of irrigated soils met the criteria to be classified as sodic soil. This indicates that the low ECe and high ESP tend to de-flocculate soil aggregates and, hence, lower their permeability to water (Fourati et al., 2015).

Impact of irrigation hazards on crop yields: Naturally, plants have different hazard tolerance capacities; some crops have greater tolerance to produces acceptable yields at much higher salinity than others. The intent of this section is to scrutinize the impacts of irrigation induced hazards on agricultural yield of main crops cultivated in Raya valley area in relation to their threshold salinity tolerance capacities. The relative salinity tolerance of most agricultural crops has been studied by number of researches that enables to give general salt tolerance guidelines. Since it is the most influential water quality guideline on crop productivity and is a strong function of the total dissolved ionic solids, electrical conductivity of the soil saturation extract (ECe) taken in the average root-zone, is used as a standard measure of soil salinity and to express relative tolerance capacities of crop tolerance (Sarkar et al., 2021). According to their threshold soil salinity level (t), crops are divided into four categories: Sensitive (S) for t < 1.3, Moderately sensitive (MS) 1.3 < t < 3.0, Moderately tolerant (MT) 3.0 < t< 6.0 , and Tolerant (T) 6 < t< 10 dS /m [15].The expected yield (Y) of a crop grown at a specific soil salinity can be calculated by Equation 3.

$Y_{(ECe)} = 100 - S(EC_e - t)$(3)

Where:$Y_{(ECe)}$: is yield potential at actual soil salinity ECe , ECe : is the electrical conductivity of the soil saturation extract (dS /m), t : is threshold value of crops where the yield decrease begins, and S: is the linear rate of yield loss. Main crops grown in the Raya valley area (sorghum, corn (maize), Teff, pepper, Tomato, cabbage and onions) and their threshold salinity tolerance capacities are summarized (Table 6).

As (Table 6), the existing soilsalinity is high enough to cause 4 - 16% yield reduction in sensitive and moderately sensitive local crops. Thus, there is need an appropriate salinity/sodicity mitigation or controlling strategy as well as efficient irrigation management practices. Proper plant selection is one way to moderate yield reductions caused by excessive soil salinity. Generally, field and forage crops have more salt tolerance capacities than vegetable crops and fruit trees (Sun et al., 2015). The growth stage of a crop also has direct effect on salt tolerance capacity, many crops have little tolerance for salinity during seed germination, but can increases significantly during later growth stages. Some crops such as barley, wheat and corn are known to be more sensitive to salinity during the early growth period than during germination and later growth periods (Choudhary et al., 2011).

Table 4: Classification of groundwater wells within the study area based on the mean values of the individual year'sdeceptive statistics during 2010 – 2020 and total average of irrigation indices.

Parameter	Symbol	Unit	Avg. ±SDV	Index class	Potential irrigation Hazard [10,11, 42]
Salinity :	TDS	PPm	813.6 ±379	S-M)	Affects crop water availability ;may have detrimental effects on sensitive crops
	ECW	dS/m	0.83 ±0.7	S-M	
Sodicity :	SAR	-	2.34 ±1.6	None	Safe
	ESP	-	28.5 ±450	S-M	affects water infiltration rate into soil
Toxicity :	Na^+	PPm	83.87 ±15.8	S-M	Affects sensitive crops. Moderately tolerant plants usually show slight to substantial injury
	Cl^-		151 ±69	S-M	
Miscellaneous	HCO_3^-	ppm	425 ±113	S-M	Increase the sodicity hazard of the soil-water to a level greater than indicated by the SAR value. effects Susceptible crops

Table 5: Classification of salt-affected soils according to NRCS reprinted from Richards (1954).

Parameter	symbol	Unit	(Avg.$\pm SD$)	Degree of hazard
Salinity	ECe	dS/m	2.22±1.92	Moderate effect on Water availability for crops
Sodicity	SAR	-	4.86±4.1	Can affect affects water infiltration rate into soils
	ESP	-	22.3±18.9	
Toxicity	Na^+	ppm	211.92±133	Affects Moderately sensitive crops. Plants usually show slight to substantial injury.
	Cl^-	ppm	59±9.8	
Miscellaneous	HCO_3^-	ppm	60±**100**	Increase the sodicity hazard of the soil-water to a level greater than indicated by the SAR value. affects Susceptible crops

Table 6: Main crops in the study area and their tolerance capacities

Crops	Permissible limits for Salinity (dS/m)		Toxicity (Ppm)		Impacts		
	ECw	EC_e (t)	$[Na^+]$	$[Cl^-]$	S	Y(ECe)	% yield loss
Sorghum	4.5	6.8	460	350	16	100	0
Maize	1.2	1.8	230	525	12	93.76	6.2
Teff	1.3	2	460	700	7.3	100	0
Tomato	1.7	2.5	46	875	9.9	100	0
Pepper	1	1.5	230	525	14	89.9	10.1
Cabbage	1.2	1.8	230	525	9.6	93.1	6.9
Onion	0.8	1.2	230	350	9.7	95.926	4.1

Conclusion

In the present study, the status of groundwater quality for irrigation and possible quality deterioration issues for over a 10-year irrigated soil characteristics as well as impacts of salinity on yields of the most local crops have been investigated . Primary parameters of borehole water and irrigated soil samples : total salinity (TDS , EC) , sodicity (SAR, ESP) , and specific ion toxicity (Na^+, Cl^- and HCO_3^-) have been collected from number of to date research findings. Although, evaluation showed that both boreholes waters and irrigated soils are found in a slight to moderate irrigation hazards categories, potential soil quality deterioration hazard and agricultural yield reduction risks for many sensitive crops can be expected. The traditional surface canal irrigation system has been facilitated the occurrence of these hazards in the irrigation schemes. The resultant of statistical data analysis infers 4 - 16% yield reduction can be expected for many sensitive and moderately sensitive irrigated crops due to the existing soil salinity. The information presented herein highlights, that the full production capability of irrigated agriculture in the Raya Valley is being impacted. For this reason, there is needs a critical analysis in selection an appropriate mitigation or controlling strategy and proper crop types for optimizing agricultural productivity. The we anticipated that the outcome could contribute to multi-criteria decision support in designing appropriate irrigation systems and efficient management practices that should be adjusted at the farm level for sustainable utility of resources. The outcome of this work can be used as a platform to design appropriate irrigation systems and efficient management practices. Based on the tangible information of the outcome, it is possible to design an efficient hazard mitigation or controlling strategic plans and section of tolerant crops for cultivation. Thus, the ultimate objectives of the study is to contribute roles in circumvention of the exacerbating water and irrigated soil quality deteriorations. Hence the result can be used as staircase in alleviating the growing food insecurity challenges through sound land use practices and sustainable utility of resources.

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