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CASE STUDY

Implications of irrigation water quality in tropical farms

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ABSTRACT

BACKGROUND AND OBJECTIVES: Irrigation system water quality is a complex issue that involves the combined effects of various surface water management parameters. Monitoring of irrigation water quality is essential for the sustainability of crop production and productivity. The department of Sucre, in northern Colombia, is predominantly a ranching and agricultural region where agriculture is the main source for livelihoods. The purpose of this study was to assess the physicochemical quality of surface water in irrigation systems at 141 farms.

METHODS: To this end, 141 water samples were taken to determine 22 physicochemical parameters. All in-situ measurements and laboratory analysis were performed using standard methods. The results obtained were compared with the international standards proposed by the United Nations' Food and Agriculture Organization and the World Health Organization. Salinity and sodicity were measured using the irrigation water classification diagram, and the level of correlation between the 22 variables was assessed by means of correlation analysis.

FINDINGS: The results obtained indicate that based on the measured parameters, the water is classified as appropriate for use in irrigation systems. The maximum and minimum pH values were 9.32 and 4.40, respectively; the maximum and minimum values of electrical conductivity were 669 and 19.80 µS/cm respectively; the maximum and minimum values of total dissolved solids were 478 and 11.80 mg/L respectively, and the maximum and minimum values of the sodium adsorption ratio were 1.72 and 0.01 mEq/L, respectively.

CONCLUSION: Cation and anion concentrations were within the limits allowed by the Food and Agriculture Organization and the WHO. According to the irrigation water classification diagram, the waters were classified as C1S1 and C2S1, which implies that there are no restrictions for their use in irrigation systems, water type (I) and type (II).

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INTRODUCTION

Developing countries are vulnerable to issues related to water pollution, mainly due to bad habits in the use of water resources and to rapid industrialization (Faye, 2019; Kushal, 2015). Traditionally, farmers irrigate using surface water, and it is estimated that the irrigation of farmlands consumes between 33 and 90% of the world's water sources, which makes irrigation an activity that affects water availability (Betancourt Aguilar *et al.*, 2017). According to the Intergovernmental Panel on Climate Change (IPCC), agriculture uses 70% of fresh water worldwide (IPCC, 2019; Yan *et al.*, 2021); and in countries such as Colombia, water consumption in agricultural activities (IDEAM, 2012), and especially in irrigation systems, accounts for 50-74% of the total (FAO, 2015). Water used for irrigation systems depends on its quality (Gómez *et al.*, 2015), which implies that it is necessary to assess its physical, chemical, and biological parameters to determine whether it is appropriate for use in the soils (Douti *et al.*, 2021). It is extremely recommended that continuous monitoring of physico-chemical parameters in order to generate useful data and information to be used as a future basis in management actions that would help in mitigating problems in water resource (Douti *et al.*, 2021; Dumago *et al.*, 2018). Monitoring of irrigation water quality is essential for the sustainability of crop production and productivity. Despite this, not much information is available on the quality of the water used for irrigation in tropical areas that are vulnerable to the effects of climate change and with few management activities, mainly on the effects that the salinity and sodicity of the water used for irrigation may have, which is associated with high levels of electrical conductivity (EC) and a high sodium adsorption ratio (SAR). In general, salinity and sodicity produce abiotic stress, which affects morphological, physiological, and biochemical processes, including seed germination, growth, and water and mineral absorption, which reduce plant yields, quality, and productivity. It additionally affects the osmotic potential of soils, which produces hydric tress and toxic effects on plants, giving rise to metabolic and nutritional disorders, and in certain conditions of soil texture in may produce reduced yields, lower water infiltration, the formation of crusts on the surface and clogging of pores, which may end up degrading the soil and increasing runoff (Bauder *et al.*, 2019; Li and Kang, 2020; Sekhon *et al.*, 2020; Taghizadehghasab *et al.*, 2021). Regardless of its source, irrigation water contains some dissolved salts. Medina Valdovinos *et al*. (2016) and Zaman *et al.* (2018) indicate that water quality for irrigation is determined by the nature, quantity, and proportion of ions present. Also, the suitability of water for irrigation is determined not only by the quantity of salts present, but also by the type of salts (Valles-Aragón *et al.*, 2017; Zaman *et al.*, 2018). Several authors have defined the main variables that should be taken into consideration to classify the quality of water for irrigation systems from an agricultural perspective, some of the most important of which include: the concentration of soluble salts, the relative concentration of sodium (Na) with respect to other cations, the concentration of boron (B) or other elements that may be toxic under certain conditions, and the concentration of bicarbonates in relation to the concentration of calcium (Ca) and magnesium (Mg) (Gómez *et al.*, 2015; Haritash *et al.*, 2016; Zaman *et al.*, 2018). Also, water used for irrigation is exposed to pollution from runoff, industrial discharges, use of agricultural chemicals and infiltration, among others, which may have significant short-term effects on the physicochemical characteristics of the water, and in turn on soil productivity and crop quality (Douti *et al.*, 2021; Kushal, 2015); and in the long term may produce changes in the edaphic properties of soil, possibly to the point of making lands unsuitable for agriculture (Bortolini *et al.*, 2018). On the other hand, water quality can have a negative effect on the performance of an irrigation system due to plugging of emitters and sprinklers. Problems can be caused by inorganic solids (silt and sand), organic solids (algae, bacteria, and slime) and dissolved solids (calcium, iron, and manganese). Potential problems can be minimized by testing the water quality to avoid potential issues (Lamont, 2012). As a tool to assess the suitability of water quality for irrigation, irrigation and water resource authorities from several countries and international organizations such as the FAO have proposed classification and monitoring methodologies (Adeyemi *et al.*, 2017). FAO is currently developing a tool monitor water and soil based on field data, models, and satellite images. The tool will help countries monitor indicators of the Sustainable Development Goals (SDGs) associated with water quality (FAO, 2021). Additionally, each country has regulations on the use of water for irrigation, supported by international standards. In Colombia, the water quality of irrigation systems is determined based on the parameters established in decree 1076/2015, the Single Regulatory Decree of the Environment and Sustainable Development Sector, which establishes certain water quality parameters for use in agricultural activities (MINIAMBIENTE, 2015). However, this decree is insufficient for determining the water quality for irrigation, because at present the water used for irrigation is from different sources, including underground and surface waters. Due to the above, most studies in Colombia rely on international standards (Guerrero Guio *et al*., 2021), which contain threshold values based on criteria such as optimal crop yields, crop quality, suitability of the soil and irrigation equipment maintenance (Afed Ullah *et al.,* 2018). Even though such standards are specific for defined areas, they are the only points of reference available in the literature. Based on the above, the need arises to set clear and precise parameters to determine the maximum and minimum values of minerals, metals, pH, EC, and SAR that water used for irrigation in Colombia should have, to contribute the required nutrients to both the crops and the soils to achieve good yields and productivity, and to help mitigate the effects of climate change. Only a handful of studies have been made in Colombia and no studies have been carried out in the northern region of the country (Caribbean region). One noteworthy study was carried out on the plateau surrounding Bogotá (Colombia's capital), which determined the water quality for irrigation in horticulture crops around influence of the Bogotá River, one of the most polluted rivers in Colombia (Miranda *et al*., 2008). González Castillo *et al*. (2020) carried out the characterization of irrigation water at 90 farms in Norte de Santander (northeastern Colombia), which were proposed for the establishment of 18 agro-ecological models. Lastly, Guerrero Guio *et al*. (2021) assessed the quality of irrigation in eight municipalities in Boyacá (in eastern Colombia) at 60 ecological farms. In this sense, studies are required to establish a baseline for the development of agricultural policies and the establishment of management actions that promote the sustainable development and food security of small farmers. The aims of the current study is to determine physicochemical water quality and assess its suitability for irrigation. This study has been carried out in irrigation systems at 141 properties owned by small farmers in the department of Sucre (northern Colombia) in five prioritized municipalities (San Onofre, San Marcos, Morroa, Corozal and Majagual). The field measurements and laboratory analysis were carried out in 2020.

MATERIALS AND METHODS

Survey design and data collection

The department of Sucre is one of the 32 departments in Colombia (South America). It is located in the northwest of the country in the Caribbean region. It limits to the north with the department of Bolívar, to the south with the department of Córdoba and to the east with the Caribbean Sea (Fig. 1). Sucre has an area of 10917 Km^2 and a population of 949252 (Bustamante *et al*., 2016), of which 37.7% are small farmers. The agricultural production of small producers in the department of Sucre is carried out under limited management practices, they carry out manual tillage, have little soil management and make an inappropriate use of agrochemicals (DNP, 2003). Additionally, small producers do not document the frequency, quantity and agrochemicals used. Common crops in the study area include corn, cassava, yams, and plantains. The department of Sucre has 26 municipalities that make up five sub-region (Table 1).

Five municipalities were selected in the study namely, Corozal, Morroa, San Onofre, San Marcos, and Majagual for the subregions of savanna, Montes de Maria, Golfo de Morrosquillo, San Jorge, and Mojana, respectively (Fig. 1). The water used for irrigation in the subregions comes from artificial ponds, which are supplied by runoff from rainwater. The commonly used irrigation methods is sprinkler irrigation. The five sub-regions were selected taking as criteria the number of farms, the number of inhabitants and the representativeness of the main crops of the Department. Likewise, easy road access was considered. The selected municipalities have the minimum access roads required for the transportation of supplies, as well as for accessibility for monitoring and collecting samples. It should be noted that the department of Sucre has deficient road infrastructure due to the serious social and economic problems caused by the conflict and violence (Lissbrant *et al*., 2018). In the selected municipalities, assessments were carried using 22 variables of analysis of the

Table 1: Characteristics of the five sub-regions of the department of Sucre, in northern Colombia.

Subregion/Area	Municipality	Average Temperature (°C)	Annual Precipitation (mm)	Location	Vegetation
Montes de María (6466 km^2)	Morroa	26.8	1000 – 1200	9° 20′ N, 75° 18′ W	Tropical dry forest area, mountain landscape
Sabana (2101 km^2)	Corozal	27	990 – 1275	9° 9′ N, 75° 18′W	Tropical dry forest area, hills landscapes
Golfo de Morrosquillo (1886 km^2)	San Onofre	27.4	900 – 1200	9° 8′ N, 75° 31′ W	Tropical dry forest area
San Jorge (2934 km^2)	San Marcos	28	1300 –2300	8° 40′ N, 75° 8′ W	Zone of tropical humid forest, tropical dry forest, tropical very dry forest, and natural savanna
Mojana (2337 km^2)	Majagual	28	2800	8° 32′ N 74° 37′ W	Tropical humid forest area

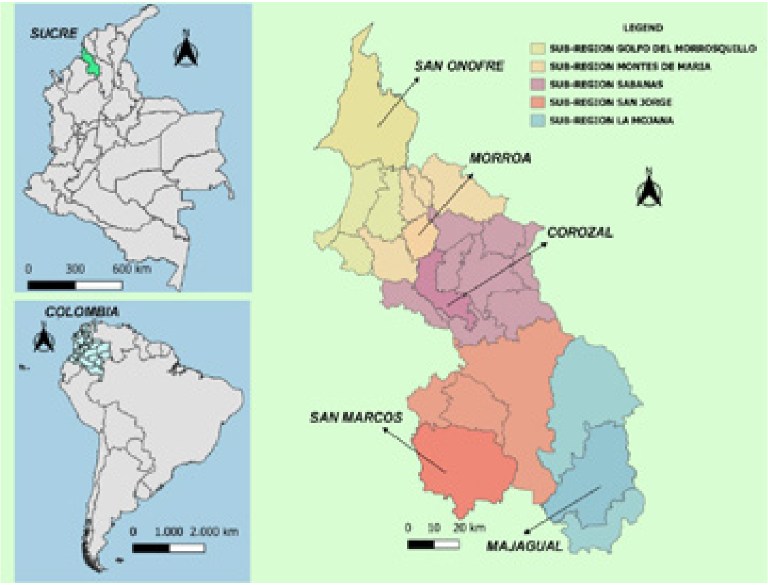

Fig. 1: Geographic location of the study area in the Department of Sucre in Northern Colombia

water used for irrigation at 141 farms.

The 141 surface water samples were gathered at the five prioritized municipalities with the following distribution: 34 samples from San Onofre, 30 samples from Morroa, 38 samples from Corozal, 17 samples from San Marcos and 22 samples from Majagual. For the sampling sites selection, the Guide for monitoring of discharges, surface and groundwater was used (IDEAM, 2002), in which the factors and criteria for sampling sites location in surface water bodies are established. The samples were gathered by the environmental laboratory Zonas Costeras S.A.S., which has been certified for environmental characterizations by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM, by its acronym in Spanish). The water samples were taken in a 200 ml clear and water-right plastic container. All *in-situ* measurements and laboratory analysis were performed using standard methods (APHA, 2017). All the samples were collected by triplicate to determine the precision of tests and sample handling. The *in-situ* temperature was measured using the method

SM 2550 B/ electrometric, electrical conductivity (EC) was measured using the method SM 2510B/ electrometric, and pH was measured using the method SM 4500 H^+B/ electrometric.

Water quality laboratory analysis

Total dissolved solids (TDS) were determined using the method SM 2540C/ gravimetric by drying at 180°C. Total suspended solids (TSS) and total solids (TS) were determined using the methods SM 2540D and SM2540B / gravimetric by drying at 103°C – 105°C, respectively, chlorides by the method SM 4500-Cl-B /Argentometric, sulfates by the method SM 4500-SO_4^{2-}E/ Turbidimetric. For nutrients: nitrates by the method SM 4500-NO_3 E/ Reduction with Cadmium, ammoniacal nitrogen by the method SM 4500-NH_3B, C/Distillation – volumetric and total phosphorus by the method SM 4500- P B, E/Digestion (sulfuric acid – nitric acid)/ ascorbic acid – Spectrophotometry. For cations: total aluminum through an internal method, equivalent to SM 3500-Al B/ photometric; for boron, silicon, magnesium, total lead and total cadmium using the method SM 3120 B / ICP-OES. For total iron, the method used was Spectroquant Merck test Iron 114761 / photometric, hexavalent chromium by the internal method equivalent to SM 3500-Cr B/ Photometric. The sodium adsorption ratio (SAR) was obtained in relation to total calcium by SM 3500-Ca B/volumetric with EDTA, magnesium SM3500-MGB / Calculation and total sodium by EPA 6010 D /ICP- OES. All the analyses were made at the environmental laboratory Zonas Costeras, certified by IDEAM.

Analytical framework

Correlation analysis was performed to determine the level of correlation between the analyzed physicochemical parameters. Additionally, the salinity and sodicity analysis was performed based on the values obtained for EC and SAR (Tartabull Puñales and Betancourt Aguilar, 2016). Lastly, a classification diagram of irrigation water was made (Shahid and Mahmoudi, 2014). The data in this work were analyzed by using R software (R Core Team, 2020).

RESULTS AND DISCUSSION

Physicochemical water quality parameters

The water temperature at the studied farms showed a maximum value of 38.2°C and a minimum value of 19.4°C, with an average value of 31.07 ± 2.32 °C. pH displayed alkaline values, with average value of 6.87 ± 0.72, which indicates that the water had acid values, but within allowable limits for agricultural use (WHO, 2016). In a case studied carried out by the office of the governor of Karf El – Sheikh, Egypt, the average value of pH was 7.88, i.e., alkaline water that was within the threshold range established by the FAO (Jahin *et al.*, 2020), which is consistent with data obtained by other authors for the largest dam in Algeria (Bini Haroun damn), with an average value of 7.81, in general determining that the pH of water used for irrigation was between neutral and slightly alkaline (Bouaroudj *et al.*, 2019). In Colombia, in a study carried out in the department of Boyacá at 60 ecological farms, pH displayed values between 6.5 and 7.5 (Guerrero Guio *et al.*, 2021). It should be noted that several authors indicate that even though pH is not one of the main factors for determining water quality, it is useful for determining the concentrations of species dissolved in carbon, and the availability of plant nutrients (Medina Valdovinos *et al.*, 2016). However, it should be pointed out that very low pH values may produce accelerated corrosion of the irrigation systems, and very high pH values above 8.5 are often caused by high levels of bicarbonates and carbonates (Bauder *et al.*, 2019). The EC of the water displayed an average value of 171.40 ± 134.45 µS/cm. These values are within the threshold range (WHO, 2016), and are classified as water of excellent quality. However, waters with low salinity, i.e., with EC values below (200 µS /cm), can give rise to infiltration problems because they tend to wash off the soluble salts in the soil, especially Ca, and may cause degradation of the soil structure, produce crusts and a reduction in water penetration (Zaman *et al.*, 2018). In a study carried out in the geothermic provinces of Konkan, Maharashtra, India, an assessment was performed of surface, underground and thermal spring waters, which displayed maximum and minimum EC values of 3960 - 160.4 µS/cm respectively, and an average value of 1469 µS/cm, concluding that the assessed waters were within all classes of water, which indicates a high level of water fluctuation (Shah *et al.*, 2019). TDS displayed an average value of 115.36 ± 86.92 mg/L, i.e., moderate concentration. TSS and TS displayed an average value of 34.29 ± 35.07 mg/L and 152.40 ± 96.31 mg/L, respectively (Table 2). According to the classification by the FAO, the assessed waters are classified as of low to moderate hazard (INTAGRI, 2018), which makes them suitable for use in irrigation.

Contrary to the findings of this study, a study carried out in the district of Mathura, the average TDS value was 4963 mg/L, which is above the allowed limit >50%. This value was attributed to high concentrations of sodium, magnesium, calcium (Ahmed *et al.*, 2020), bicarbonates, sulfurs, and chlorides (Valles-Aragón *et al.*, 2017). Values close to those reported in this study were found in a study carried out in Jamalpur Sadar, Bangladesh, in underground and surface waters (162.2 and 287.8 mg/L, respectively) (Zakir *et al.*, 2020). TDS are thought to be consequential from runoffs, agricultural practices, deforestation activities, sewage discharges and other sources (Dumago *et al.*, 2018). Cl^- displayed an average value of (10.78 ± 9.06 mg/L), the concentrations of SO_4 and N-NO_3 displayed values of (106.86 ± 58.25 mg/L and 0.69 ± 0.16 mg/L, respectively), and N-NH_3 (4.70 ± 0.59 mg/L). Additionally, concentrations of P displayed an average value of 0.20 ± 0.26 mg/L. Aluminum concentration displayed an average value of (1.85 ± 1.84 mg/ L). Si concentrations averaged (5.35 ± 4.96 mg/L), and the average value of Fe concentration was (2.70 ± 1.85 mg/L). Irrigation water with Fe levels above 0.10 mg/L may cause clogging of drip irrigation emitters and above 0.30 mg/L may lead to Fe rust stains, and discoloration on foliage plants in overhead irrigation applications. These levels are generally below the levels that cause toxicities in plant tissue except when iron levels exceed 4 mg/L or when the root medium pH is below 5.5 (Saaltink *et al.*, 2017). The average values of Mn and B concentration were 0.13 ± 0.20 mg/L and 0.05 ± 0.03 mg/L, respectively. The concentrations of Pb, Cr and Cd displayed average values of 0.02 ± 0.008 mg/L, 0.07 ± 0.01 mg/L and 0.002 ± 0.001 mg/L, respectively, while the average values of the concentrations of Ca^{2+}, Mg^{2+} and Na were 18.52 ± 22.01 mg /L, 12.91 ± 7.73 mg/L and 3.22 ± 7.12 mg/L, respectively. Lastly, the average value of SAR was 0.14 ±0.21 mEq/L. This value is within the allowable range, with the assessed waters classified as suitable for irrigation (Arhad and Shakoor, 2017; Zaman *et al.*, 2018). SAR represents the adsorption of sodium in irrigation water and reflects the possible influence of sodium in the soil; it also has a dispersing effect on colloids in the soil and may affect soil permeability (Zaman *et al.*, 2018). The FAO states that SAR <3 does not cause problems to the crops and soils (Shahid *et al.*, 2018). Consistent with the values found in this study, a study carried out in southern Iraq (Al-Gharraf channel), with assistance from a software program named Irrigation Water Guide (IWGV.1), the average value of SAR was: 1.96 mEq/L, which indicates that the channel's water has

Table 2: Results for the physicochemical parameters analyzed in water used for irrigation in the department of Sucre, in northern Colombia

Parameter	Maximum	Minimum	Mean ± SD
T (°C)	38.20	23.90	31.07 ± 2.32
pH	9.32	4.40	6.87 ± 0.72
EC (µS/cm)	669	19.80	171.40 ± 134.45
TDS (mg/L)	478	11.80	115.36 ± 86.92
TSS (mg/L)	287	3.80	34.29 ± 35.07
TS (mg /L)	574	25	152.40 ± 96.31
Cl (mg/L)	54.80	2.40	10.78 ± 9.06
SO_4 (mg/L)	625	4.30	106.86 ± 58.25
N-NO_3 (mg/L)	1.01	0.50	0.69 ± 0.16
N-NH_3 (mg/L)	6.35	3.05	4.70 ± 0.59
P (mg/L)	1.42	0.02	0.20 ± 0.26
Al (mg/L)	11.3	0.16	1.85 ± 1.84
Si (mg/L)	33.2	0.71	5.35 ± 4.96
Fe (mg/L)	8.56	0.23	2.70 ± 1.85
Mn (mg/L)	1.62	0.002	0.13 ± 0.20
B (mg/L)	0.29	0.01	0.05 ± 0.03
Pb (mg/L)	0.05	0.01	0.02 ± 0.008
Cr^{+6} (mg/L)	0.07	0.05	0.07 ± 0.01
Cd (mg/L)	0.005	0.001	0.002 ± 0.001
Ca^{2+} (mg/L)	210	3.06	18.52 ± 22.01
Mg^{2+} (mg/L)	59.30	3.95	12.91 ± 7.73
Na (mg/L)	51.30	0.30	3.22 ± 7.12
SAR (mEq/L)	1.72	0.01	0.14 ± 0.21

low risk for irrigation (Ewaid *et al*., 2019). Meanwhile, a study carried out in Colombia at 60 ecological farms in 4 municipalities of the department of Boyacá, SAR displayed concentrations of 0.16 mEq/L for farm 4 of model 1 (Guerrero Guio *et al*., 2021).

The correlation analysis indicated statistically significant correlations between the analyzed variables (*p-value* $\leq$ 0.05) (Table 3), except for TSS and pH, which displayed no correlation with the other water quality variables. Only P displayed correlation with TSS (*p-value* $\leq$ 0.05), while Al only displayed correlation with temperature (*p-value* $\leq$ 0.05). P and Al had low negative correlation with B, Mn, Na, Cr and SAR. Even though SAR was correlated with almost all the chemical variables, it only displayed high positive correlation with Mn. Cl had high negative correlation with P and low negative correlation with Al. The correlation analysis indicates high positive correlations between the variables EC – TDS (r = 0.969), TDS – TS (r= 0,924), Cd – P (r = 0. 989), Mg – Ca^{2+} (r=0.964), Na – Mn (r=0.996), P – NH_3 (r= 0.995), Si – Cl (r= 0.995) and Na – SAR (r = 0. 919), and high negative correlation between EC – Fe (r = -0.084), Ca^{+2} – P (r = - 0.085), Mg^{+2} – Al (r = -0.084) and Cd – Mn (r =0.082). The most highly correlated variables were pH, EC, TDS, Cl, SO_4, Ca^{2+}, Mg^{2+} and B. The variable associated with the cations, anions, pH, TDS, EC, and TS was SAR (*p-value* $\leq$ 0.05); P was only associated with TSS, and Al only with temperature (*p-value* $\leq$ 0.05). In a study carried out at the largest dam in Algeria (Beni Haroun dam), 112 correlation tests were statistically significant, most of them positive, between Na, EC, Cl, K, SAR, Na% and other parameters (e.g., HCO_3). Additionally, the correlation indicated that water temperature was negatively correlated with pH, EC, Ca, Mg, Na, Cl, HCO_3, and NO_3 (Bouaroudj *et al*., 2019). As in the case of this study, most correlations were positive. A study carried out in the geothermal provinces of Konkan, Maharashtra, India, by means of a correlation matrix it was determined that strong positive correlation exists between Cl and Na (r = 0.973), Cl and EC (r=0. 994), Cl and Ca (r=0.917); TDS displayed high correlation with EC, Na, Ca, Cl, Br, indicating that it is probable that they are derived from the same water source, but displayed negative correlation with Mg and HCO_3. SO_4 displayed poor correlation with most ions and negative correlation with Mg and HCO_3 (Shah *et al*., 2019). The correlation between EC values and Ca^{2+}, Mg^{2+} and Cl reflects the large contribution of these ions to the salinity of the water assessed in the department of Sucre. Additionally, the correlation between Ca^{2+}, Mg^{2+}, Cl and Na indicates that these ions contribute in a natural manner to the salinity of the water and that they represent most of the soluble salts in the water (Jahin *et al*., 2020).

Classification of the assessed water for irrigation

Most values for electrical conductivity were below 250 µS/cm at the assessed farm units, which implies that the water is of excellent quality for use in irrigation. Values above 250 µS/cm were only found in the municipalities of Morroa and San Onofre, associated with medium water quality (Fig. 2A). Based on the sodicity found in the water for irrigation at the farm units, there is no risk of sodization, because the SAR values were <10 mEq/L, i.e., water classified as of excellent or good quality for this parameter (Fig. 2B). Most of the assessed waters from the farm units were classified as C1S1 (good water quality) and C2S1 (medium hazard water), which puts the sampled water in the category of type (I) and type (II) (Fig. 2C). C1 water can be used for most crops and most soils with low probability of developing salinity in the soil. C2 water can be used, though it may produce moderate amounts of lixiviates. It can be used for plants with moderate tolerance for salt and can be used for most crops without the need for special practices to control salinity. S1 water can be used for irrigation of almost all types of soil, without the risk of developing harmful levels of exchangeable sodium in the soil. S2 waters pose a significant sodium hazard in soils of fine texture and high capacity to exchange cations, especially in soils with low lixiviation conditions. This type of water can be used in thick texture soils or organic soils with good permeability (Zaman *et al*., 2018). Several studies on surface waters in different areas of the world display results that are consistent with or differ from the results obtained for the waters assessed in the department of Sucre. In a study carried out in Ecuador at a sustainable quinoa crop by the Togllahuayco stream, the waters were classified as C1S1, C1S2, and C2S2 (Quinteros Carabalí *et al*., 2019), which partially coincides with the classification reported in this study. Unlike the above results, a study carried out in Tunisia on the Medjerda River reported classifications of water for irrigation of C1S1, C2S1, waters with low risk of salinity, C3S3 and C4S3, waters with high risk of alkalinity and high to very high salinity, and C4S2, waters with medium sodium risk associated with very high salinity (Etteieb *et al*., 2017).

Table 3: Correlation between the assessed physicochemical properties in water used for irrigation in the department of Sucre, in northern Colombia

Parameter		pH	T	EC	TDS	TSS	TS	Cl^-	SO_4	NO_3	NH_3	Ca^{2+}	Mg^{2+}	P	Al	Fe	B	Cd	Mn	Na	Pb	Si	Cr	SAR
		p - value																						
pH	Correlation coefficient		0.000	0.000	0.000	0.934	0.000	0.087	0.095	0.573	0.736	0.003	0.071	0.465	0.060	0.182	0.043	0.000	0.581	0.014	0.022	0.217	0.779	0.005
T		0.357		0.001	0.001	0.945	0.001	0.365	0.846	0.235	0.901	0.144	0.228	0.435	0.000	0.414	0.442	0.000	0.718	0.321	0.076	0.330	0.293	0.255
EC		0.347	0.290		0.000	0.811	0.000	0.001	0.000	0.004	0.001	0.000	0.000	0.785	0.567	0.321	0.000	0.000	0.132	0.000	0.000	0.000	0.035	0.000
TDS		0.357	0.273	0.969		0.612	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.866	0.483	0.716	0.000	0.000	0.058	0.000	0.000	0.000	0.025	0.000
TSS		0.007	0.006	0.021	0.045		0.000	0.593	0.801	0.680	0.217	0.708	0.314	0.000	0.062	0.018	0.499	0.377	0.017	0.214	0.851	0.108	0.430	0.320
TS		0.337	0.266	0.884	0.924	0.412		0.005	0.000	0.002	0.000	0.000	0.000	0.120	0.135	0.640	0.000	0.000	0.005	0.000	0.000	0.000	0.064	0.000
Cl^-		0.225	-0.120	0.434	0.398	-0.074	0.362		0.060	0.400	0.631	0.066	0.006	0.338	0.736	0.124	0.000	0.044	0.665	0.002	0.343	0.995	0.008	0.007
SO_4		0.141	0.017	0.577	0.620	-0.022	0.601	0.247		0.595	0.000	0.000	0.000	0.604	0.447	0.499	0.000	0.000	0.104	0.000	0.000	0.037	0.295	0.002
NO_3		-0.048	0.101	0.243	0.310	-0.036	0.255	-0.112	0.045		0.825	0.013	0.339	0.634	0.510	0.286	0.823	0.781	0.323	0.830	0.463	0.731	0.770	0.640
NH_3		-0.029	0.011	0.290	0.324	0.108	0.334	-0.064	0.335	-0.019		0.060	0.171	0.995	0.699	0.152	0.812	0.162	0.000	0.857	0.545	0.214	0.860	0.677
Ca^{2+}		0.263	0.133	0.795	0.795	-0.035	0.727	0.248	0.836	0.225	0.171		0.000	0.365	0.621	0.064	0.000	0.000	0.964	0.000	0.000	0.007	0.698	0.000
Mg^{2+}		0.156	0.105	0.726	0.652	-0.090	0.578	0.364	0.745	0.083	0.119	0.805		0.454	0.335	0.052	0.000	0.000	0.517	0.000	0.000	0.000	0.358	0.000
P		-0.065	-0.069	-0.024	-0.015	0.411	0.138	-0.131	-0.046	0.042	-0.001	-0.085	-0.068		0.534	0.007	0.661	0.989	0.958	0.275	0.627	0.593	0.506	0.383
Al		0.066	0.306	0.049	0.060	0.163	0.127	-0.045	-0.065	0.056	-0.033	-0.045	-0.084	0.055		0.000	0.682	0.371	0.763	0.339	0.562	0.848	0.614	0.515
Fe		-0.113	0.069	-0.084	-0.031	0.205	0.040	-0.202	-0.057	-0.091	0.121	-0.168	-0.168	0.236	0.610		0.019	0.247	0.274	0.015	0.874	0.817	0.405	0.020
B		0.240	0.093	0.653	0.585	-0.083	0.528	0.475	0.762	0.027	0.029	0.871	0.809	-0.054	-0.050	-0.277		0.000	0.529	0.000	0.000	0.730	0.499	0.013
Cd		0.399	0.334	0.589	0.569	0.088	0.571	0.266	0.438	0.027	0.134	0.579	0.492	0.001	0.086	-0.111	0.673		0.397	0.000	0.000	0.134	0.032	0.000
Mn		0.047	-0.031	0.128	0.161	0.207	0.234	0.058	0.137	-0.084	0.440	0.004	0.056	-0.005	-0.026	0.093	-0.076	-0.082		0.996	0.240	0.230	0.896	0.877
Na		0.210	0.085	0.650	0.554	-0.110	0.455	0.399	0.526	-0.018	-0.016	0.607	0.803	-0.097	-0.082	-0.207	0.550	0.434	0.000		0.000	0.000	0.291	0.000
Pb		0.345	0.271	0.691	0.674	-0.031	0.653	0.190	0.768	0.114	0.094	0.904	0.769	-0.076	0.090	-0.025	0.837	0.584	0.181	0.624		0.002	0.812	0.008
Si		0.105	0.083	0.375	0.392	0.140	0.361	0.001	0.175	0.029	0.105	0.242	0.337	0.048	0.016	0.020	0.042	0.144	0.102	0.379	0.461		0.616	0.000
Cr		0.024	-0.089	0.178	0.190	-0.069	0.157	0.343	0.089	-0.025	-0.015	0.036	0.080	-0.059	-0.043	-0.071	0.082	0.205	-0.011	0.091	0.037	0.043		0.326
SAR		0.238	0.097	0.583	0.501	-0.087	0.413	0.348	0.263	-0.040	-0.035	0.340	0.575	-0.077	-0.055	-0.196	0.293	0.329	0.013	0.919	0.398	0.393	0.083	

EC= Electrical conductivity; T= Temperature; TDS= Total Dissolved Solids; TSS= Total Suspended Solids; TS=Total Solids; SAR= Sodium Adsorption Ratio.

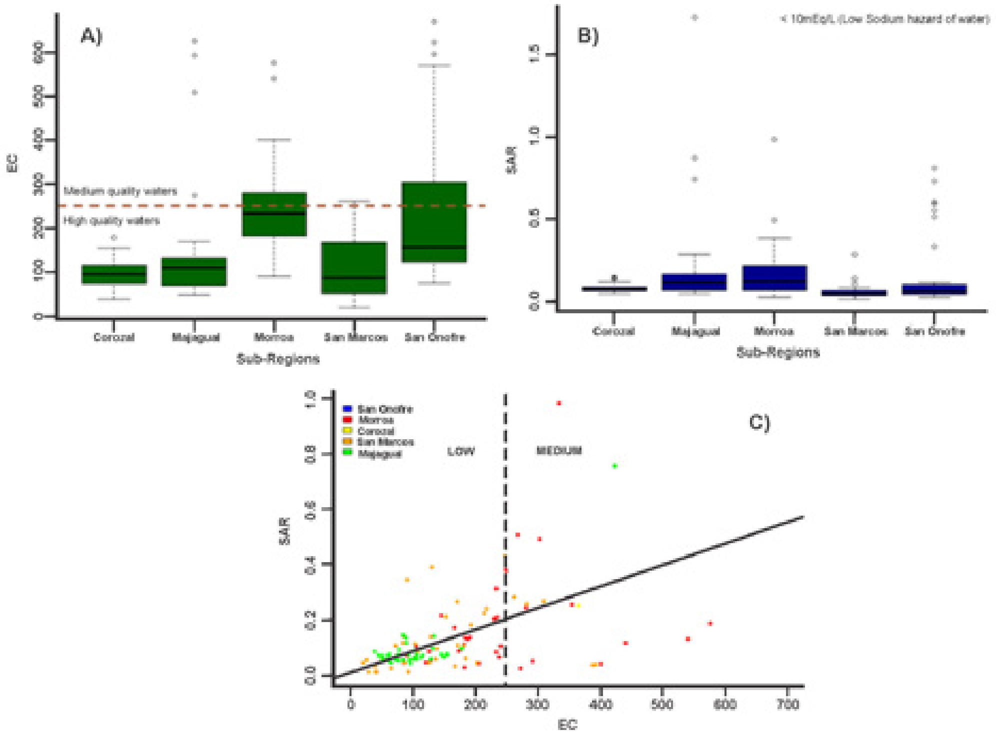

Fig. 2: A) Hazard level according to electrical conductivity. B) Sodization level. C) Sodium adsorption ratio (SAR) vs electrical conductivity (EC)

CONCLUSION

Irrigation systems depends on water quality, which implies that it is necessary to assess its physical, chemical, and biological parameters to determine whether it is appropriate for use in the soils. This study highlighted the need to evaluate the quality of irrigation systems water for crop and soil health, and to guide farmers on the implications of use of low-quality irrigation water. The surface waters assessed at the 141 farm units of the prioritized municipalities of the department of Sucre, Colombia, are waters that are suitable for use in irrigation systems, because according to the FAO and WHO they are waters that are within the established thresholds for use in agriculture, without producing harm to the crops and the soils. The concentrations of cations and anions in the water, such as Na, SO_4, Cl, Ca^{2+}, Mg^{2+}, which are generally associated with increased salinity, were within the allowed ranges, which implies that the water is suitable for irrigation. The concentrations of EC and SAR associated with salinity and sodicity displayed optimal levels, based on which they were classified as C1S1 and C2S1 waters. Some EC results displayed very low levels, due to which it is advisable to monitor these waters to avoid possible future problems for the soils and crops. Additionally, the correlation between EC values and Ca^{2+}, Mg^{2+} and Cl reflects the large contribution of these ions to the salinity of the water assessed in the department of Sucre. However, the irrigation water had an average Fe value above 0.30 mg/L. The study revealed that important concentration levels and composition of dissolved constituents in water which determine its quality for irrigation use were found within the permissible limits for irrigation water. It is recommended to perform periodic testing of the water, because external factors and chemical agents may change the composition of the water, directly affecting the crops and agricultural soils. Based on the sodicity found in the water for irrigation at the farm units, there is no risk of sodization, because the SAR values were <10 mEq/L, i.e., water classified as of excellent or good quality for this parameter. The FAO states that SAR <3 does not cause problems to the crops and soils. Lastly, this study establishes a baseline for the development of agricultural policies and the establishment of actions that promote the sustainable development and food security of small farmers in tropical zones that are vulnerable to the effects of climate change and with few management activities.

AUTHOR CONTRIBUTION

B. Guerra Tamara performed the literature review, experimental design, analyzed and interpreted the data, prepared the original draft. A.C. Torregroza-Espinosa performed analyzed and interpreted the data, writing - original draft, writing - review & editing. D. Pinto Osorio helped in the contextualization and prepared the original draft. M.I. Moreno Pallares performed literature review, experimental design, analyzed and interpreted the data, writing - original draft, writing - review & editing. A. Corrales Paternina helped in the contextualization and prepared the original draft. A. Echeverría-González helped in the contextualization and prepared the original draft.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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ABBREVIATIONS

Al	Total Aluminum
B	Boron
Br	Bromide
°C	Degree Celsius
Ca	Calcium
C1	Low salinity water
C2	Medium salinity water
C3	High salinity water
C4	Very high salinity water
Ca^2	Total calcium
Cd	Total cadmium
Cl	chlorides
Cr	Hexavalent chromium
C1S1	Good water quality
C2S1	Low sodium water
C2S2	Medium salinity water
C3S3	High sodium water
C4S3	Very high sodium water
EC	Electrical conductivity
FAO	Food and Agriculture Organization
Fe	Iron
HCO_3	baking soda
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies
IWGV.1	Irrigation water guide
IPCC	Intergovernmental Panel on Climate Change
K	Potassium
Mg^2	Magnesium
Mg/L	Milligrams per liter
mEg/L	Milliequivalents per liter
mm	millimeter
Mn	Magnesium
Na	sodium
N-No3	Nitrates
$N\text{-}NH_3$	Ammoniacal nitrogen
ODS	Sustainable Development Goals
P	Total phosphorus
Pb	Total lead
pH	Hydrogen potential
µS/cm	Microsiemens per centimeter
S1	Low sodium water
S2	Medium sodium water
S3	High sodium water
S4	Very high sodium water
SAR	Sodium adsorption ratio
Si	Silicon
SO_4	Sulfate
SM2550B/ electrometric	Standard Method for the analysis of water and wastewater
SM/2510B/ electrometric	Standard Method for the analysis of water wastewater

SM/4500/H+B/ electrometric	Standard Method for measuring the pH value in water by potentiometry using a standard hydrogen electrode
SM/2540C/ gravimetric	Standard Methods: Total Dissolved solids dried at 180 °C
SM/2540D/ gravimetric	Standard Methods: Total Suspended solids dried at 103-105 °C
SM/2540B/ gravimetric	Standard Method: Total Suspended solids dried at 103 -105°C
SM4500-Cl-B Argentometric	Standard Methods: Chloride by argentometric method
SM4500 SO42 – E turbidimetric	Standard Methods: sulfate
SM 4500-NO3 E/ Reduction with Cadmium	Standard Methods: Nitrate in Water After Cadmium Reduction
SM 4500-NH3B, C/Distillation – volumetric	Standard Methods: nitrogen (ammonia)
SM 4500- P B, E/ Digestion (sulfuric acid – nitric acid)/ ascorbic acid – Spectrophotometry	Standard Methods: phosphorus
SM 3500-Al B/ photometric	Standard Methods: Aluminum by Eriochrome Cyanine R Method
SM 3120 B / ICP-OES	Standard Methods: Metals by plasma emission spectroscopy
SM 3500-Cr B/ Photometric	Standard Methods: Chromium
SM 3500-Ca B/ volumetric with EDTA	Standard Methods: Calcium by EDTA
SM3500-MGB / Calculation and total sodium	Standard Methods: Calculation and total sodium
TDS	Total dissolved solids
TSS	Total suspended solids
TS	Total solids
WHO	World Health Organization

REFERENCES

Adeyemi, O.; Grove, I.; Peets, S.; Norton, T., (2017). Advanced Monitoring and Management Systems for Improving Sustainability in Precision Irrigation. Sustainability, 9: 353 **(29 pages)**.

Afed Ullah, K.; Jiang, J.; Wang, P., (2018). Land use impacts on surface water quality by statistical approaches. Global J. Environ. Sci. Manage., 4(2): 231-250 **(20 pages)**.

Ahmed, S.; Khurshid, S.; Madan, R.; Abu Amarah, B.A.; Naushad, M., (2020). Water quality assessment of shallow aquifer based on Canadian Council of Ministers of the environment index and its impact on irrigation of Mathura District, Uttar Pradesh. J. King Saud. Univ. - Sci., 32: 1218–1225 **(8 pages)**.

American Public Health Association – APHA, (2017). Standard methods for examination of water and wastewater. 23rd Ed. Washington DC, USA **(1546 pages)**.

Arhad, M.; Shakoor, A., (2017). Irrigation water quality. Water Int., 12(1-2): 145-160 **(17 pages)**.

Bauder, T.A.; Waskom, R.M.; Sutherland, P.L.; Davis, J.G., (2019). Irrigation Water Quality Criteria. Irrigation With Reclaimed Municipal Wastewater - A Guidance Manual, 1-4 **(4 pages)**.

Betancourt Aguilar, C.; Tartabull Puñales, T.; Labaut Betancourt, Y., (2017). El manejo integrado del agua en la agricultura: necesidad de implementación y aspectos vinculados. Revista para la Transformación Agraria Sostenible, 5: 40-54 **(15 pages)**.

Bouaroudj, S.; Menad, A.; Bounamous, A.; Ali-Khodja, H.; Gherib, A.; Weigel, D.E.; Chenchouni, H., (2019). Assessment of water quality at the largest dam in Algeria (Beni Haroun Dam) and effects of irrigation on soil characteristics of agricultural lands. Chemosphere, 219: 76–88 **(13 pages)**.

Bortolini, L.; Maucieri, C.; Borin, M., (2018). A Tool for the Evaluation of Irrigation Water Quality in the Arid and Semi-Arid Regions. Agronomy. 8: 23 **(15 pages)**.

Bustamante, N.; Danoucaras, N.; McIntyre, N.; Díaz-Martínez J.; Restrepo-Baena, O.J., (2016). Review of improving the water management for the informal gold mining in Colombia. Revista Facultad de Ingeniería Universidad de Antioquia, 79: 174-184 **(11 pages)**.

DNP, (2003). Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO). Programa de Desarrollo sostenible de la región de La Mojana, Bogotá. Departamento Nacional de Planeación **(567 pages)**.

Douti, N.; Ebenezer, A.; Abanyie, S., (2021). Irrigation water quality and its impact on the physicochemical and microbiological contamination of vegetables produced from market gardening: a case of the Vea Irrigation Dam, U.E.R. Ghana. J. Water Health, 19 (2): 203–215 **(13 pages)**.

Dumago, S.W.L.; Puno, G.R.; Ingotan, S.S., (2018). Water quality assessment in various land use and land cover of Muleta Watershed Bukidnon, Philippines. J. Biodivers. Environ. Sci., 12(3): 201-209 **(9 pages)**.

Etteieb, S.; Cherif, S.; Tarhouni, J., (2017). Hydrochemical assessment of water quality for irrigation: a case study of the Medjerda River in Tunisia. Appl. Water Sci., 7: 469–480 **(11 pages)**.

Ewaid, S.H.; Kadhum, S.A.; Abed, S.A.; Salih, R.M., (2019). Development and evaluation of irrigation water quality guide using IWQG V.1 software: A case study of Al-Gharraf Canal, Southern Iraq. Environ. Technol. Innov., 13: 224–232 **(8 pages)**.

FAO, (2015). AQUASTAT Perfil de país Colombia. Food and Agriculture Organization of the United Nations **(21 pages)**.

FAO, (2021). Water quality land and water. Food and Agriculture Organization of the United Nations Land and Water.

Faye, C., (2019). Water Resources and Their Management in an Increasing Urban Demography: The Case of Dakar City in Senegal, Resources of Water, Prathna Thanjavur Chandrasekaran, Muhammad Salik Javaid, Aftab Sadiq. IntechOpen **(20 pages)**.

Gómez, C.; José, J.; Muñoz, B.; Rodríguez, H.; Lourdes, M., (2015). Calidad del agua para riego en la agricultura protegida en Tlaxcala. Revista Académica de la FI-UDAY, 19(1): 39-50 **(12 pages)**.

González Castillo, L.; Thomas Manzano, J.; Hernández Tabaco, B., (2020). Caracterización del agua de riego en 90 fincas propuestas para 18 modelos agroecológicos en Norte de Santander, Colombia. Inge CUC, 16(2): 1-15 **(15 pages)**.

Guerrero Guio, J.; Castillo González, L.; Rodríguez Cely, N., (2021). Calidad de agua para riego de 60 finca agroecológicas de 4 municipios del departamento de Boyacá. Inge CUC, 17(1): 1-16 **(16 pages)**.

Haritash, A.K.; Gaur, S.; Garg, S., (2016). Assessment of water quality and suitability analysis of River Ganga in Rishikesh, India. Appl. Water Sci., 6: 383–392 **(10 pages)**.

IDEAM, (2002). Guide for the monitoring of discharges, surface water and groundwater. Bogotá D.C. nstituto de Hidrología, Meteorología y Estudios Ambientales **(587 pages)**.

IDEAM, (2012). Demanda agua - Instituto de Hidrología, Meteorología y Estudios Ambientales.

INTAGRI, (2018). Clasificación de agua para riego Agrícola. Serie de Agua y Riego. No. 20. Artículo técnico de Instituto para la Innovación Tecnológica en Agricultura , 5: 1-5 **(5 pages)**.

IPCC, (2019). Climate Change and Land. Intergovernmental Panel on Climate Change **(41 pages)**.

Jahin, H.S.; Abuzaid, A.S.; Abdellatif, A.D., (2020). Using multivariate analysis to develop irrigation water quality index for surface water in Kafr El-Sheikh Governorate, Egypt. Environ. Technol. Innov., 17: 100532 **(12 pages)**.

Kushal, R., (2015). Irrigation water quality assessment and identification of river pollution sources in Bangladesh: Implications in policy and management. J. Water Resour. Hydraul. Eng., 4: 303–317 **(14 pages)**.

Lamont, B., (2012). Maintaining Drip Irrigation Systems. Penn State Extension **(6 pages)**.

Li, X.; Kang, Y., (2020). Agricultural utilization and vegetation establishment on saline-sodic soils using a water–salt regulation method for scheduled drip irrigation. Agric. Water Manage., 231: 105995 **(11 pages)**.

Lissbrant, S.; Espitia, P.J.P.; Mendoza, A., (2018). Challenges faced by smallholder farmers in a former conflict area in Colombia: the case of Montes de María. Investigación y Desarrollo, 26(2): 6-39 **(34 pages)**.

Medina Valdovinos, E.K.; Mancilla Villa, O.R.; Larios, M.M.; Guevara Gutiérrez, R.D.; Olguín López, J.L.; Barreto García, O.A., (2016). Quality water for irrigation and agricultural land in tuxcacuesco, jalisco. Idesia, 34(6): 51–59 **(6 pages)**.

MINIAMBIENTE, (2015). Decreto 1076. Ministerio del Medio Ambiente y Desarrollo Sostenible **(654 pages)**.

Miranda, D.; Carranza, C.; Fischer, G., (2008). Calidad de agua de riego en la sabana de Bogotá. 1rd. Ed. Gente Nueva Editorial **(252 pages)**.

Quinteros Carabalí, J.A.; Gómez-García, J.; Solano, M.; Llumiquinga, G.; Burgos, C.; Carrera-Villacrés, D., (2019). Evaluación de la calidad de agua para riego y aprovechamiento del recurso hídrico de la quebrada Togllahuayco. Siembra, 6: 46-57 **(12 pages)**.

R Core Team, (2020). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

Saaltink, R.M.; Dekker, S.C.; Eppinga, M.B.; Griffioen, J.; Wassen, M.J., (2017). Plant-specific effects of iron-toxicity in wetlands. Plant Soil, 416: 83–96 **(14 pages)**.

Sekhon, K.S.; Kaur, A.; Thaman, S.; Sidhu, A.S.; Garg, N.; Choudhary, O.P.; Buttar, G.S.; Chawla, N., (2020). Irrigation water quality and mulching effects on tuber yield and soil properties in potato (Solanum tuberosum L.) under semi-arid conditions of Indian Punjab. F. Crop. Res., 247:107544 **(11 pages)**.

Shah, B.; Kansara, B.; Shankar, J.; Soni, M.; Bhimjiyani, P.; Bhanushali, T.; Shah, M.; Sircar, A., (2019). Reckoning of water quality for irrigation and drinking purposes in the konkan geothermal provinces, Maharashtra, India. Groundw. Sustainable Dev., 9: 1-10 **(10 pages)**.

Shahid, S. A.; Mahmoudi, H. (2014). National strategy to improve plant and animal production in the United Arab Emirates. Soil and water resources Annexes.

Shahid, S.A.; Zaman, M.; Heng, L., (2018). Introduction to Soil Salinity, Sodicity and Diagnostics Techniques. In: Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques. 1st. Ed. Springer open **(183 pages)**.

Taghizadehghasab, A.; Safadoust, A.; Mosaddeghi, M.R., (2021). Effects of salinity and sodicity of water on friability of two texturally-different soils at different matric potentials. Soil Tillage Res., 209: 104950 **(11 pages)**.

Tartabull Puñales, T.; Betancourt Aguilar, C., (2016). La calidad del agua para el riego. Principales indicadores de medida y procesos que la impactan. Agro-ecosistemas. 4: 46-60 **(15 pages)**.

Valles-Aragón, M.C.; Ojeda-Barrios, D.L.; Guerrero-Prieto, V.M.; Prieto-Amparan, J.A.; Sánchez-Chávez, E., (2017). Calidad del agua para riego en una zona nogalera del estado de Chihuahua. Rev. Int. Contam. Ambient., 33: 85-97 **(13 pages)**.

WHO, (2016). Guías para la calidad del agua potable: Recomendaciones. World Health Organization **(408 pages)**.

Yan, S.; Gao, Y.; Tian, M.; Tian, Y.; Li, J.,(2021). Comprehensive evaluation of effects of various carbon-rich amendments on tomato production under continuous saline water irrigation: Overall soil quality, plant nutrient uptake, crop yields and fruit quality. Agric. Water Manage., 255: 106995 **(12 pages)**.

Zakir, H. M; Sharmin, S; Rahman, S., (2020). Assessment of health risk of heavy metals and water quality indices for irrigation and drinking suitability of waters: a case study of Jamalpur Sadar are, Bangladesh. Environ. Adv., 2: 100005 **(14 pages)**.

Zaman, M.; Shahid, S. A.; Heng, L., (2018). Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques. In: Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques. 1st. Ed. Springer open **(183 pages)**.

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