Suitability and assessment of the dams water for the purpose of agricultural irrigation

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Abstract: This study was carried out to evaluate the water quality of selected dam lakes as well as their suitability for agricultural irrigation. Seven dams were selected for water sampling and samples were collected monthly, including during the irrigation season for a period of one year from March to September 2019. The samples were analyzed for temperature, pH, physicochemical parameters such as temperature, pH value, salinity (EC), anions (CO_3, HCO_3, CI, SO_4, P, NO_3), cations (Na, K, Ca, Mg, B, NH_4) and heavy metals. The irrigation suitability assessment was made using various indices such as SAR (sodium adsorption rate), TDS (total dissolved solids), Na% (sodium percentage), RSC (residual sodium bicarbonate), MAR (magnesium adsorption rate), KR (Kelly ratio), and PI (permeability index). The temperature values of the water samples varied between 5.8ºC-25.1ºC, pH and EC values changed between 7.51 and 8.46, 282, and 1400 μS/cm respectively. The water samples were evaluated as C_2S_1 and C_3S_1 irrigation water classes. The heavy metal contents of the water samples were determined below the limit values. Selected dams were found suitable for irrigation in terms of EC (salinity), SAR (sodium adsorption rate), TDS (total dissolved solids), Na% (sodium percentage), RSC (residual sodium bicarbonate), MAR (magnesium adsorption rate), and KR (Kelly ratio). Water samples were determined as the second class of PI (permeability index). Güllübağ dam was not found suitable as irrigation water in terms of EC, Na%, RSC, and KR values. As a result, it specifically points to the restrictions on the use of water from the Güllübağ dam for irrigation purposes.

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1 Introduction

Water is becoming an increasingly limited resource. Water quality and its suitability for all types of water use are determined according to the degree of risk that will occur in long-term use[1,2]. Approximately 70% of the water in the world is used for agricultural irrigation. The quantity and quality of irrigation water are crucial factors in agricultural production for both the short and long term[3-5]. Especially in long-term irrigation, the major irrigation water quality problems are sodicity, salinity, and alkalinity caused by the presence of large amounts of ions in water, affecting soil's chemical and physical properties causing reduce soil productivity[6].

Several researchers reported that water used for irrigation depends primarily on quantity and type of dissolved salts, which influences its quality and suitability. Researchers reported that assessing water quality for irrigation purposes, the following key water qualities such as pH, salinity (EC), Ca, Mg, Na, K, CO_3, HCO_3, CI, SO_4, B, NO_3 and PO_4 ions concentrations must be measured[7].

Especially in long-term irrigation, the major factors[5,8]. For example, boron, sodium, and chloride are the salts that can cause the most serious toxicity problems to plants. Some crops are sensitive to boron, so it is often included in the analysis. Some of these cations are beneficial for crop production at low concentrations. Otherwise, they affect soil's properties, cause plants' toxicity, and make management practices difficult[9]. To deal with such problems, information concerning the quality of irrigation water and its effect on soils and crops is necessary[10].

Evaluating the quality of irrigation water must into account its chemical characteristics, for example, the type and quantity of anions and cations present in it[5,8]. For example, boron, sodium and chloride are the salts that can cause the most serious toxicity problems to plants. Some crops are sensitive to boron, so it is often included in the analysis. Some of these cations are beneficial for crop production at low concentrations. Otherwise, they affect soil's properties, cause plants' toxicity, and make management practices difficult[9]. To deal with such problems, information concerning the quality of irrigation water and its effect on soils and crops is necessary[10].

Irrigation water can contain a different concentration of contaminants including heavy metals, which can pollute the agricultural soil and crop plants with potential environmental and human health risks[11]. Examples of these heavy metals are Zn, Cu, Fe, Cd, Cr, and others. Certainly, for plants Zn and Cu are essential for their growth, however, they usually become harmful at high concentrations. However, some heavy metals, namely cadmium (Cd), lead (Pb) and chromium (Cr), are even harmful at low concentrations[12]. The actual concentration of an element in water that will cause toxic symptoms varies, depending on the crop[13].

Different water quality classification system has been

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established to use various types of water for irrigation and to predict the problems that may arise during their use[14]. Water infiltration problems can occur when certain sodium content levels are surpassed in the soil with those of calcium and magnesium, known as the sodium adsorption ratio. The water quality studies are mostly based on hydrochemical parameters[15]. The common indices used to assess the suitability of water for irrigation are; percent sodium (Na%), residual sodium bicarbonate (RSC), Kelly's ratio (KR), permeability index (PI), magnesium adsorption ratio (MAR), sodium adsorption ratio (SAR)[16].

The main objectives of this study are to 1) assess the chemical properties of the dam's water such as basic anions, cations, and heavy metals; 2) to determine the water quality of dam water for agriculture irrigation through evaluation of various agricultural water parameters such as EC, sodium adsorption ratio (SAR), percent sodium (Na%), residual sodium carbonate (RSC), Kelley Ratio (KR), magnesium hazard (MAR) and permeability index (PI). The result of this study will guide irrigation water use and sustainable irrigation development in the region.

2 Materials and methods

2.1 Information on study area

Uşak Province (pronounced Ushak) is a city in the inner Aegean Region of Turkey with an area of 5556 km². The agricultural area of 2194 km², which corresponds to 39% of the province's surface area is above the Turkey average. The geographical coordinates of Uşak province are 38.5431°N, and 29.2321°E (Figure 1). Selected dams and irrigation areas were shown on the graphic map (Figure 2). The construction dates and capacities of the selected dams were given in Figure 2 also.

Figure 1 Location of Uşak province in Turkey

2.2 Water sampling and methods of analysis

Water samples were taken during the irrigation season for a one-year period from March to September 2019. The samples were taken from the lower outlet weirs of the dam. Temperature, pH, and EC values were determined at the place where water samples were taken using a pH meter and EC meter. Samples were collected from the polyethylene (PE) bottles of 1.0 L which are put in the icebox and taken away to the General Directorate of State Hydraulic Works 2. Regional Directorates Research Laboratory Bornova, İzmir. A total of 147 water samples were collected in the study area.

Samples were analyzed in the laboratory for the physicochemical properties such as cations and anions; sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and anions like carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3), ammonium (NH_4^-) and boron (B) in the laboratory using the standard methods given by the APHA[17]. Trace elements and heavy metals were determined in water samples also. Samples were acidified by the addition of 3 mol HNO_3 before the analysis. Elemental analyses were determined by using ICP OES (inductively coupled plasma optic emission spectrometry) (Perkin Elmer Optima 2100 DV).

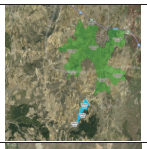
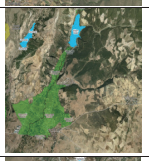
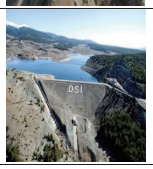
	View of the dams		Construction dates	Irrigation area/ hm²
Küçükler dam			2008	1475
Ahat dam			2008	557
Korvizan dam			2012	663
Karaköse dam			2014	511
Derbent dam			2015	438
Güllübağ dam			2015	95
Gögem dam			2016	521

Figure 2 Irrigation area of selected dams and view of the dams

2.3 Determination of irrigation water quality

Use of poor irrgation water quality can create four types of problems, namely toxicity, water infiltration, salinity and hardness. For current irrigation water quality assessment, the following parameters were considered. EC, SAR, Na%, RSC, KR, MAR and PI are important parameters for determining the suitability of water sources for irrigation[18].

Chemical indicators (Na%, SAR, MAR, RSC, KR, PI) were derived using Equations (1) to (6)[9-13].

$$\text{Sodium Percentage}\left(\text{Na}\%\right)=\frac{(\text{Na}+\text{K})}{(\text{Na}+\text{K}+\text{Ca}+\text{Mg})}\times 100\% \quad (1)$$

$$\text{Sodium absorption ratio}\,(\text{SAR})=\frac{\text{Na}}{\sqrt{\left(\text{Ca}+\text{Mg}\right)/2}} \quad (2)$$

$$\text{Magnesium adsorption ratio}\ (\text{MAR})=\frac{\text{Mg}}{(\text{Ca}+\text{Mg})}\times 100\% \quad (3)$$

$$\text{Residual sodium bicarbonate}\ (\text{RSC})=(\text{CO}_3+\text{HCO}_3)-(\text{Ca}+\text{Mg}) \quad (4)$$

$$\text{Kelley's Ratio}\ (\text{KR})=\frac{\text{Na}}{\text{Ca}+\text{Mg}} \quad (5)$$

$$\text{Permeability index (PI)} = \frac{\left(\text{Na} + \sqrt{\text{HCO}_3}\right)}{(\text{Ca} + \text{Mg} + \text{Na})} \times 100\% \quad (6)$$

3 Result and discussion

3.1 Temperature, pH, EC, anions and cations

The minimum, maximum and average values of the water samples were given in Table 1. The temperature of the water samples varied from 5.8ºC at the lowest to 25ºC at the highest depending on the sampling time. These values were suitable for allowable irrigation water standards (<25ºC). Temperature is one of the most important physical characteristics of water ecosystems. Water temperature is also an important factor as it indirectly affects water quality parameters[19]. According to the Surface Water Quality Regulation, the water samples of the selected dams were evaluated as Class I[20]. Water temperature typically increases linearly with air temperature from about 0°C to 20°C. On a watershed scale, hydrology can impact stream water temperatures[21].

Table 1 The concentration of anions and cations in water samples

Parameters	Küçükler	Kozviran	Ahat	Karaköse	Göğem	Derbent	Güllübağ
Temperature/ºC	7.4[a]-25.0[b]	7.6-24.9	8.7-25.1	5.8-25.0	10.2-25.0	9.5-24.0	10.5-23.5
	17.9[c]	17.9	18.4	17.4	18.9	18.3	18.0
pH	7.96-8.46	7.73-7.85	7.62-8.46	7.75-8.20	7.65-8.44	8.13-8.48	7.51-8.11
	8.17	7.78	8.06	7.98	7.93	8.23	7.81
EC/μS·cm^{-1}	483-599	727-1010	282-296	402-417	442-465	633-687	1170-1400
	524	898	291	409	455	655	1290
Na/mg·L^{-1}	2.22-3.17	4.30-21.8	5.25-5.40	3.26-3.48	9.42-9.84	15.8-17.3	113-140
	2.72	10.6	5.32	3.35	9.58	16.6	125
K/mg·L^{-1}	1.20-1.48	2.30-3.66	2.60-3.21	1.54-1.74	6.01-6.24	6.04-6.97	39.5-45.4
	1.25	2.96	2.93	1.63	6.11	6.39	41.88
Ca/mg·L^{-1}	52.0-63.0	82.5-120	44.5-47.7	58.8-69.4	42.9-44.2	36.0-56.2	63.5-80.0
	56.10	104.48	46.14	65.62	44.18	45.44	71.46
Mg/mg·L^{-1}	31.3-41.2	42.5-55.5	6.75-7.18	11.2-12.2	25.9-27.7	46.4-51.9	21.0-26.7
	35.0	50.3	7.0	11.8	27.1	49.5	24.3
CO_3^{2-}/mg·L^{-1}	trace-12.1	trace-trace	trace-trace	trace-trace	trace-26.4	trace-39.9	trace-trace
	9.77				16.9	23.6	
HCO_3^-/mg·L^{-1}	177-225	313-338	153-154	195-231	152-240	233-373	267-489
	197.3	321.9	153.4	219.4	190.6	260.1	448.8
Cl/mg·L^{-1}	2.74-3.78	5.29-33.4	6.46-7.13	3.57-3.88	8.15-9.96	20.6-22.6	163-206
	3.20	14.78	6.70	3.75	9.03	21.44	182.70
SO_4^{2-}/mg·L^{-1}	84.9-120.1	53.4-189.9	9.57-10.05	21.0-24.5	31.5-45.6	77.1-89.8	13.5-25.2
	102.7	141.7	9.82	22.3	38.6	83.6	17.9
NH_4^+/mg·L^{-1}	trace-trace	trace-1.6	trace-trace	trace-0.22	0.20-0.53	trace-0.25	32.7-36.9
		0.86		0.10	0.41	0.11	34.1
NO_3^-/mg·L^{-1}	0.29-0.43	0.23-0.56	0.58-0.98	0.19-0.27	0.40-0.88	0.19-1.09	0.38-1.11
	0.34	0.43	0.81	0.23	0.59	0.51	0.69
P/mg·L^{-1}	trace-0.13	trace-0.14	trace-trace	trace-trace	0.13-0.24	trace-0.20	6.65-14.2
	0.08	0.08			0.19	0.11	9.89
B/mg·L^{-1}	0.09-0.13	0.08-0.09	0.08-0.09	0.08-0.09	0.08-0.09	0.09-0.26	0.57-0.80
	0.11	0.08	0.08	0.08	0.08	0.17	0.68

Note: a. mimimum value, b. maximum value, and c mean value.

The pH values of the dam's water ranged from 7.51 to 8.48, depending on the sampling time. The pH value of the Ahat and Gögem dams was found to be higher than the standard reported by the FAO. Acceptable pH values for irrigation water range from 6.80 to 8.40. The hydrogen ionic potential (pH) is one of the parameters that characterize the quality of water for irrigation and can and the cation exchange process between soil and plant[22].

Electrical conductivity is an indication of the concentration of total dissolved solids and major ions in a given irrigation and drinking water resource[10]. The EC value of the water samples ranged from the lowest 291 μS/cm in the Ahat dam to 1290 μS/cm in the Güllübağ dam, which is the highest. The EC levels of the Güllübağ dam water were above the 1000 μS/cm allowed by FAO and posed a threat to crops due to its high EC value. Other dams can continue to be used for irrigation purposes and it can be said that they do not pose any danger of salinity on the territory of the irrigation basin area.

The concentrations of cations and anions in the water samples are given in Table 1. The average sodium concentration of the dam water samples ranged from 2.72 to 125 mg/L. The highest value was found at 140 mg/L in the Güllübağ dam and the lowest value was found at 2.22 mg/L in the Küçükler dam (Table 1). K concentration was determined at least 1.25 mg/L in the Küçükler dam and the highest 42.88 mg/L was detected in the Güllübağ dam. The lowest and highest Ca amount was determined as 7.0 mg/L in Ahat dam and 50.3 mg/L in Kozviran dam, respectively. The Ca concentration was determined as 44.18 mg/L in Gögem dam and 104.48 mg/L in Kozviran dam. Table 1 showed that Ca was dominant among the cations in the sampling time, which constitutes a higher proportion of the total cations compared to the other cations.

Based on anion, such as CO_3^{2-} concentrations were determined between trace and 39.9 mg/L in water samples. CO_3^{2-} anion was

determined only in Küçükler, Gögem and Derbent dam waters. The mean values of HCO_3 concentrations varied between 153.4 and 448.8 mg/L The highest amount was determined in the Güllübağ dam, while the lowest value was observed in the Ahat dam (Table 1). Irrigation water containing CO_3^{2-} higher than 30 mg/L and HCO_3^- more than 610 mg/L are not generally recommended. From this point of view, the dam water samples can be used for long-term irrigation use[1]. The Cl concentrations of water samples varied between 3.20 and 182.7 mg/L. The highest concentration of CI was determined at the Güllübağ dam.The most common crop toxicity is caused by CI in irrigation water. Chlorides are necessary for plant growth, though in high concentrations they can inhibit plant growth, and can be highly toxic to some plant species. The SO_4 concentration in water samples was determined between 9.72 mg/L and 141.7 mg/L also. Similar to Ca in the cations, bicarbonate is the dominant anion during the sampling time; hence, the waters of selected dams are mild alkaline. Among the cations and anions, the concentrations of Ca, Mg, Na, K, CO_3, HCO_3, CI, and SO_4 ions are of paramount importance in irrigation water assessment.

The concentrations of NO_3, NH_4, P, and B in water samples were determined within the study. The concentration of NO_3 and NH_4, P and B in the water of the selected dam was determined between 0.19-1.11 mg/L, trace-36.9 mg/L, trace-9.89 mg/L, and 0.08-0.80 mg/L respectively.

The NH_4 concentration was determined higher (32.7-36.9 mg/L) in the Güllübağ dam compared with other dam water. Most of the nitrogen in irrigation water is in the form of nitrate (NO_3), but some ammonium (NH_4) may also be present. According to FAO, the NO_3 concentrations are within permissible limits (<5 mg/L). High amounts of NO_3 can be harmful to human health and the environment, especially with P, eutrophication poses a serious problem. It was determined that B concentrations in the selected dams did not exceed the limits for even sensitive crops. The B concentration in irrigation water should be lower than 0.3 mg/L to prevent toxicity.

3.2 Trace elements and heavy metals

The results of the minimum, maximum, and average values of heavy metals and trace elements are given in Table 2. Trace elements are not included in the routine analysis of irrigation water, but heavy metal analyzes are especially performed when contamination by industrial wastewater discharges is suspected.

Table 2 Heavy metals concentration of water samples and recommended maximum concentrations of trace elements in irrigation water

Trace elements and hevay metals	Küçükler	Kozviran	Ahat	Karaköse	Göğem	Derbent	Güllübağ	Limit value[1]
Aluminium/$\mu g \cdot L^{-1}$	trace[a]-3.31[b] 2.74[c]	trace-trace	2.98-4.31 3.48	trace-trace	trace-3.63 2.77	trace-14.4 7.03	7.45-23.9 13.7	5000
Arsenic/$\mu g \cdot L^{-1}$	1.83-5.13 3.56	6.31-48.1 21.72	1.88-2.80 2.55	1.88-2.13 2.13	1.88-7.95 7.57	24.9-35.8 29.41	7.42-11.6 9.29	100
Beryllium/$\mu g \cdot L^{-1}$	trace-trace	trace-trace	trace-trace	trace-trace	trace-trace	trace-trace	trace-trace	100
Boron/$\mu g \cdot L^{-1}$	90-130 110	80-90 85.0	80-90 85.0	80-90 85.0	80-90 85.0	90-260 175	570-800 685	1000
Cadmium, $\mu g \cdot L^{-1}$	trace	trace	trace	trace	trace	trace	trace	10
Cobalt/$\mu g \cdot L^{-1}$	trace	0.23-2.58 2.07	trace	trace	0.23-0.61 0.46	0.23-0.37 0.30	0.79-1.28 1.05	50
Copper/$\mu g \cdot L^{-1}$	1.10-3.72 2.15	1.29-6.87 3.56	0.81-1.35 1.12	0.77-1.21 1.02	1.41-2.40 2.01	0.88-5.49 3.83	0.88-26.6 9.51	200
Chromium/$\mu g \cdot L^{-1}$	trace-7.24 4.59	trace-9.69 5.84	trace-2.04 1.98	trace-5.33 3.08	trace	trace	trace-22.8 11.7	100
Fluoride/$mg \cdot L^{-1}$	trace-0.25 0.11	trace-0.11 0.09	0.10-0.27 0.16	0.13-0.24 0.17	0.15-0.42 0.25	0.18-0.54 0.37	0.78-2.22 1.56	1.00
Iron/$mg \cdot L^{-1}$	trace	trace-0.09 0.04	trace	trace	trace-0.02 0.016	trace-0.035 0.021	0.09-0.43 0.21	5.00
Lead/$mg \cdot L^{-1}$	trace-0.63 0.34	trace	trace	trace	trace	trace	trace	5.0
Lithium/$mg \cdot L^{-1}$	trace	trace	trace	trace	trace	trace	trace	2.5
Manganese/$\mu g \cdot L^{-1}$	3.60-8.95 6.62	trace-2160 1400	trace-16.23 7.77	trace-19.0 8.56	trace-135 52.3	trace-92.9 33.2	571-804 723.6	200
Molybdenum/$\mu g \cdot L^{-1}$	0.46-0.53 0.50	0.37-1.39 0.95	0.23-0.29 0.27	0.35-0.51 0.44	0.44-0.72 0.59	1.25-1.40 1.30	0.30-1.11 0.58	10
Nickel/$\mu g \cdot L^{-1}$	7.95-13.4 10.70	7.08-17.1 13.03	2.68-4.09 3.51	3.20-6.52 4.69	9.43-12.2 10.91	8.80-41.0 19.40	5.25-18.0 11.24	200
Selenium/$\mu g \cdot L^{-1}$	trace	trace	trace	trace	trace	trace	trace	20
Mercury/$\mu g \cdot L^{-1}$	trace	trace	trace	trace	trace	trace	trace	
Vanadium/$\mu g \cdot L^{-1}$	trace	trace	trace	trace	trace	trace	1.98-7.48 4.91	100
Zinc/$\mu g \cdot L^{-1}$	trace-18.2 11.1	trace-63.3 38.0	trace-14.0 6.52	trace-9.57 5.85	trace-14.5 7.20	trace-76.4 27.3	trace-32.8 13.6	2000

Note: a. mimimum value, b. maximum value, and c mean value.

According to the water analysis, no problems were detected in the dam waters in terms of trace elements and heavy metals. Analysis results were below the limit values specified in both irrigation water and surface water quality regulations. Güllübağ and Kozviran dams were above the limit values in terms of Mn and F content. However, the soils where the selected dams were used as irrigation water were basic in character. Therefore, it was concluded that using it for irrigation purposes would not cause any problems in terms of heavy metals and trace elements content. Irrigation is an important factor in the improvement of productivity efforts because, for adequate development of the plants, sufficient amounts of trace elements found in water are needed but if the water used for irrigation is contaminated it creates a toxic impact on the production of water reservoir having different characteristics are used in the agricultural usage[23]. Generally, the contamination of agricultural soils with heavy metals through irrigation water is primarily due to irrigation water sourced from deep wells or polluted rivers, lakes, and channels[24,25]. Heavy metals in the aquatic system can remain for some time as they are not readily degraded. Naturally, heavy metals are found at low concentrations in the natural waters, where their high concentrations in water and sediments indicate that they come from anthropogenic rather than geogenic origin[26,27].

3.3 Determination of irrigation water quality

The minimum, maximum and average water quality indices in water samples including TDS, Na%, SAR, MAR, RSC, KR, PI were given in Table 3 At the same time, the evaluation limit values of the irrigation water quality indices and the classification of the dams are given in Table 4.

Table 3 The water quality parameters of the irrigation dams

Parameters	Küçükler (1)	Kozviran (2)	Ahat (3)	Karaköse (4)	Göğem (5)	Derbent (6)	Güllübağ (7)
TDS/mg·L^{-1}	344[a]-400[b]	501-708	185-206	268-283	288-327	441-474	782-1038
	361[c]	611	198	279	310	454	893
Na/%	2.26-2.83	3.05-9.30	9.05-10.2	4.02-4.60	11.1-11.7	11.3-13.2	52.8-54.6
	2.56	5.41	9.58	4.21	11.4	12.1	53.4
SAR	0.06-0.08	0.10-0.42	0.19-0.20	0.10-0.11	0.27-0.28	0.38-0.43	3.14-3.48
	0.07	0.21	0.19	0.10	0.28	0.41	3.26
MAR	50.0-52.2	42.3-46.2	20.0-20.3	22.1-25.8	50.1-51.1	57.9-70.6	35.6-37.1
	51.0	44.5	20.2	23.0	50.6	64.5	36.2
RSC	–1.86 to -2.64	–1.88 to -5.01	–0.03 to -0.22	–1.12 to 0.08	–0.40 to -1.14	–1.39 to -1.66	1.34-2.63
	–2.19	–3.89	–0.13	0.42	–0.89	–1.53	2.01
KR	0.02-0.02	0.02-0.09	0.08-0.08	0.03-0.04	0.09-0.10	0.10-0.12	0.94-1.00
	0.02	0.05	0.08	0.03	0.09	0.11	0.97
PI	30.7-34.2	23.7-32.4	56.5-60.1	42.0-51.1	40.4-48.2	35.9-41.7	72.5-74.9
	32.8	27.9	58.2	46.3	44.7	39.1	73.9
IWC	C2S1	C3S1	C2S1	C2S1	C2S1	C2S1	C3S1

Note: IWC: Irrigation water class. a. mimimum value, b. maximum value, and c. mean value.

The TDS value of the water of the selected dam ranged from the lowest value of 185 mg/L at the Ahat dam to the highest of 1038 mg/L at the Güllübağ dam. According to the results, the Küçükler Dam, Ahat Dam, Karaköse Dam, and Göğem Dam were in the "low" class for the safe use of water for irrigation. The Kozviran Dam, Derbent Dam, and Güllübağ Dam were determined in the "middle" class. TDS values above 1000 mg/L result in yield decreases for salt-sensitive crops and even salt-tolerant plants around 2000 mg/L can show significant yield decreases[1],

Water used for irrigation can vary greatly in quality depending upon the type and quantity of dissolved salts. In dam water, salts are present in relatively small but significant amounts. The salts originate from the dissolution or weathering of the rocks and soil, including the dissolution of lime, gypsum, and other slowly dissolved soil minerals. The dissolved salts remain behind in the soil as water is used up by crops or evaporates[28]. Dissolved solids can also contribute to clogging problems in drip irrigation systems[1]. High and very high salinity water is not suitable for irrigation under ordinary conditions. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and plants with very good salt tolerance should be selected. It is also important to consider the TDS in water, because many of the toxic solid materials may cause harm to plants[10].

Sodium concentration is important in classifying irrigation. The suitability of water for irrigation is based on Na%. Sodium is an important cation, which in excess deteriorates the soil structure and reduces crop yield[29,30]. When the concentration of sodium is high in irrigation water, it will tend to be adsorbed by clay particles displacing Mg and Ca ions. This exchange process of sodium in water for Mg and Ca ions in soil reduces the permeability and finally results in soil with poor internal drainage. The mean values of Na% of the dam water samples ranged from 2.03% to 45.0%. Especially Güllübağ dam was found the highest (45.0%) in terms of Na% content. Other dams were determined between 2.03 and 10.0.

The mean SAR values of the water samples were determined between 0.07 and 3.26 (Table 3). From Table 4, the SAR values of the water samples allow the water to be classified as excellent for irrigation The water having SAR<10 is good for irrigation. It was observed that all the sites studied were good for irrigation. The SAR value is an easily measured property that gives information on the comparative concentrations of Na, Ca, and Mg ions in soil solutions. The High SAR in any irrigation water implies the hazard of sodium replacing Ca and Mg of the soil through the cation exchange process, a situation eventually damaging to soil structure, namely permeability which ultimately affects the fertility status of the soil and reduces crop yield[31]. Using a US Salinity Laboratory diagram to plot the SAR versus the EC value provides more

information on the suitability of water for irrigation. The results of this study indicate that the dams were in a "C_2S_1; medium salinity with low sodium" and "C_3S_1; high salinity with low sodium" hazard as listed in Table 4. Kozviran and Güllübağ dams can be used for irrigation with most crops under special management for salinity control due to their high salinity hazards.

Table 4 Water quality parameters of selected irrigation dams

Parameters	Range	Class	Dams
EC, electrical conductivity/μS·cm^{-1}	<250	Low	
	250-750	Medium	1,2,3,4,5,6
	750-2250	High	7
	>2250	Very high	
SAR, sodium absorption ratio	0-10	Use for all soil types	1,2,3,4,5,6,7
	10-18	Preferably use on coarse-textured soil	
	18-26	May produce a harmful effect, good soil management is required	
	>26	Unsuitable	
TDS, total dissolved solids/mg·L^{-1}	500	None (Water for which no detrimental effects will usually be noticed)	1,3,4,5,6
	500-1000	Some (Water that may have detrimental effects on sensitive crops)	2
	1000-2000	Moderate (Water that may have adverse effects on many crops, thus requiring careful management practices)	7
	2000-5000	Severe (Water that can be used for salt-tolerant plants on permeable soils with careful management practices)	
Na, sodium percentage/%	<20	Excellent	1,2,3,4,5,6
	20-40	Good	
	40-60	Permissible	7
	60-80	Doubtful	
	>80	Unsuitable	
RSC, residual sodium bicarbonate	<1.25	Good	1,2,3,4,5,6
	1.25-2.5	Medium	7
	>2.5	Unsuitable	
MAR, magnesium adsorption ratio	<50	Suitable	2,3,4,7
	>50	Unsuitable	1,5,6
KR, kelly ratio	<1	Suitable	1,2,3,4,5,6
	>1	Unsuitable	7
PI, permeability index	<25	Class III (suitable)	
	25-75	Class II (Moderate)	1,2,3,4,5,6,7
	>75	Class1 (unsuitable)	

The calcium and magnesium in most waters maintain a state of equilibrium. A high level of MAR (>50%) in a water sample causes soil alkalinity; moreover, a considerable quantity of water is adsorbed between magnesium and clay particles, reducing the soil's infiltration ability and negatively impacting crop yields[32,33]. Results from this research showed that only Korvizan, Ahat, Karaköse and Güllübağ dams of the water samples were MAR<50% while Küçükler, Gögen and Derbent dams were above the permissible limit of 50%. When these waters are used for irrigation for a long time, the crops are detrimentally affected and the soil becomes more saline.

RSC is a useful index for assessing the suitability of irrigation water because it evaluates the relationship between the quantity of carbonate and bicarbonate and the total calcium and magnesium[33]. As the water in the soil becomes more concentrated, waters with high concentrations of HCO_3 have a propensity to precipitate Ca and Mg cations. As a result of the deposition of sodium carbonate, soils watered with high RSC water might become unproductive[34]. Irrigation is typically deemed safe when RSC levels are less than 1.25 meq/L. Water with an RSC of 1.25 to 2.50 meq/L is classified as marginal RSC levels of more than 2.5 meq/L and is considered inappropriate for irrigation. In the study, the RSC values were in the range of a minimum of −5.01 to a maximum of +2.63 (Table 3). The RSC values were evaluated within the safe limits except for the Güllübağ dam (1.34-2.63 meq/L).

The concentration of Na, Ca, and Mg in the water represents the alkali hazard. The values of KR<1 indicate good quality water for irrigation KR>1 indicates bad water. The Kelly Ratio of the water sample was in a range between 0.02 to 1.00. The minimum value of KR was observed at Küçükler Dam while the maximum at Güllübağ Dam. Therefore, according to KR most of the dams of water samples were suitable for irrigation. But, the Güllübağ Dam was not suitable for irrigation due to the excess sodium in the water.

The soil permeability is affected by the long-term use of irrigation water. Factors to determine soil permeability are sodium content relative to calcium and magnesium; bicarbonates and carbonate content, and the total salt concentration of the water[1,35]. The results showed that the PI of the mean value of water samples ranged between 27.9 and 73.9 (Table 4). Water samples were evaluated as moderately suitable for PI. A permeability problem related to water quality may occur when the rate of water infiltration into and through the soils is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with rate and yield is reduced.

4 Conclusions

The water qualities of selected dams were assessed. The concentrations of the Ca, Mg, Na, K, CO_3, HCO_3, CI, SO_4, B, NO_3,

and PO_4 ions and heavy metals were analyzed. Evaluation of irrigation water quality of selected dams was carried out using different indexes methods such as EC, SAR, TDS, Na%, RSC, MAR, KR, and PI.

The result indicates that the Küçükler, Ahat, and Karaköse dams were found to be within limit values such as pH, EC, major constituents (anions, cations, nitrate, ammonium, phosphorus, bor, chloride minor constituents (heavy metals and trace elements). Therefore water from these dams can be used for irrigation purposes. Korvizan and Güllübağ dams were determined in the second and third classes in terms of TDS. Therefore, these dams can have negative effects on many crops and require careful management practices.

The Küçükler, Gögem, and Derbent dam can not be used for irrigation purposes in terms of MAR. Güllübağ dam was not found suitable as irrigation water in terms of EC, Na%, RSC, and KR. The selected dams were evaluated in the second class (good) in terms of PI. Generally, the water of the selected dams has good characteristics as irrigation water, except for a few cases that require a special careful application.

The US salinity diagram revealed that the surface water samples of the selected dams during the sampling time belong to the categories (S_1C_2; medium salinity, and low sodium hazard) and (S_1C_3; high salinity, and low sodium hazard), respectively. Thus, the selected dam's water is suitable for irrigation of most soils (except soils with low salt tolerance) with little danger of the emergence of harmful levels of exchangeable sodium. Soils and crops with good salt tolerance are recommended and a special treatment of salinity might be required.

Some measures should be taken especially in the case of using the Güllübağ dam for irrigation purposes such as soil characteristics of the irrigation area, the sensitivity of the selected plant, irrigation water amount, etc.

Accordingly, the dams used for agricultural irrigation should be protected from the negative impacts of environmental problems. The qualities and contents of the dam's water and soil by using irrigation waters should be subjected to analyses periodically for monitoring the properties of water reservoirs.

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