Irrigation Water Quality Assessment for Water Resources Used in Irrigation of Agricultural Fields of Kütahya - Alayunt Village

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Abstract— *This study was conducted to assess the irrigation water quality of deep wells in Kütahya- Alayunt village and to assess the salinity-alkalinity of agricultural fields irrigated with these waters. The pH values of water samples taken in May, June, July, August and September varied between 7,12 - 8,57 and electrical conductivity (EC) values varied between 563 - 1483 µmhos/cm. According to US Salinity Lab. Classification System, water samples were classified as* C_2S_1 *(moderately saline – low alkaline) and* C_3S_1 *(highly saline – low alkaline). Differences were observed in irrigation water quality criteria throughout the irrigation season. Soils of the research site had loamy (L) and clay-loam (CL) textures. Soil pH values varied between 7,23 - 7,94 and EC values varied between 485 - 1652 µmhos/cm.*

Keywords— Irrigation, irrigation water quality, soil salinity.

I. INTRODUCTION

Just because of insufficient precipitations in several regions throughout the cropping year, irrigation has become the essential component of production activities to get high quality and quantity yields. Efficient and productive use of water resources plays a great role in sustainable management of available water resources. Such issues are also quite significant for meeting the domestic water needs of increasing population (over 80 million today), water needs of developing industries and water demands of agricultural irrigations. Natural quality water supply for these uses will only be possible with proper soil and water management practices [1].

Salts in irrigation water increase osmatic pressure of soil solution and thus negatively influence plant water use. High osmatic pressure reduces plant water uptake and ultimately results in plant die out. Therefore, salinity is used as quality and classification criterion for irrigation waters [2].

Annual total precipitations in arid and semi-arid regions of the world are not sufficient in leaching soluble salts accumulated within the root zones due to evaporation and water table close to soil surface. Therefore, in land reclamation practices, current salinity problems should be well-identified and leaching-induced change in soil salinity should be well-estimated [3].

Soil salinity is among the most significant abiotic stress factors directly limiting plant production worldwide. Salt stress also directly designates plant diversity in agricultural fields. Plant response to salt stress is controlled by complex molecular mechanisms. Salt stress results in various physiological changes in plants and plants develop different tolerance mechanisms against salt stress. Such changes and differences may sometimes emerge as plant-specific mechanisms or be common in all plants. These complex mechanisms could either develop directly as a response to salt stress or be accompanied with the other mechanisms developed against the other abiotic stress factors like drought. Therefore, salt stress and plant tolerance mechanisms should be well-comprehended both at plant level and tolerance level and salt-tolerant plant cultivars should be developed accordingly [4].

Total salt concentration of irrigation waters is expressed as electrical conductivity (EC x 106) in µmhos/cm (1000µmhos/cm= 1mmhos/cm= 1dS/m). Reliable irrigation waters mostly have total salt concentrations of lower than 2250 µmhos/cm. In terms only of total salt concentrations, electrical conductivity of irrigation waters should be less than 750 µmhos/cm. However, irrigation water with electrical conductivity values of between 750 - 2250 µmhos/cm are also largely used on irrigated lands provided that proper drainage and operational conditions are provided. In case of insufficient leaching practices under improper drainage conditions, such waters may result in salinity problems in agricultural fields [5].

Anlıatamer [6] conducted a study to assess soil salinity in irrigation district of Ankara Haymana Türkşerefli Dam and indicated that Babayakup Creek merging with sub-branch of Şerefli Stream within the study area had a high electrical conductivity level, thus precautions should be taken while using this water in irrigations. It was also indicated that the increase in salinity levels of some areas was mostly resulted from unconscious irrigation practices of the farmers and application of low-quality irrigation waters through surface irrigation methods.

In another study, effects of different quality irrigation waters on alfalfa were investigated and it was reported that saline waters recessed the growth, reduced the yield and quality of alfalfa. On the other hand, when the sufficient leaching was provided and excess salt was removed from the field, plant growth and development reached back to normal levels. It was concluded that for high yield in alfalfa farming, irrigation water salinity should be less than 1.5 dSm^{-1} [7].

Gürcan [8] assessed the quality of irrigation waters in irrigation district of Ankara Haymana Soğulca Village Irrigation Cooperative and indicated that majority of irrigation water samples was classified as C_3 (highly saline) and these waters should not be used in fields with limited drainage facilities. Despite the use these saline waters in irrigations, salinity problems were not encountered in irrigated lands. However, it was also indicated that for potential salinity problems not to be encountered in the future, open or underground drainage systems should be constructed in these fields.

Topçu and Taş [9] conducted a study on Çanakkale Biga Plain and assessed electrical conductivity (EC), pH, potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), carbonate (CO_3), bicarbonate (HCO_3), chlorine (Cl), sulphate (SO_4), nitrate (NO_3) and boron (B) parameters of irrigation water samples taken from 20 different groundwater wells. Samples were classified based on Water Pollution Control Regulation of Turkey. In terms of salinity, 11 of 20 samples were classified as the second-class and the rest was classified as the first-class. Apart from nitrate pollution, generally no problem was encountered in study area during the study period.

Demer and Hepdeniz [10] conducted a study on Isparta Plain and assessed the water quality parameters of samples taken from 21 groundwater wells and reported the quality class of some water samples as C_3S_1 (highly saline – low alkaline) and the quality class of the rest as C_2S_1 (moderately saline – low alkaline).

It was indicated in another study conducted in Left-Bank of Menemen irrigation district that improper irrigation methods and low water use efficiencies resulted in rising groundwater levels. High water tables negatively influence agricultural productions, thus to prevent high groundwater levels, either proper drainage facilities should be constructed or already available ones should be rehabilitated and maintained [11].

Dorak and Çelik [12] conducted a study to determine the effects of domestic and industrial wastewater effluents on water quality of Nilüfer Creek by taking water samples from the effluents of 5 treatment plants discharging their effluents into Nilüfer Creek and from the streams receiving effluents of these treatments in 4 different periods between August 2013 – May 2014. It was indicated that wastewater quality parameters varied with the sampling periods and in terms of EC and SAR, water samples were classified as between C_2S_1 - C_4S_4 classes. Quality parameters of water samples taken before and after discharge of treated effluents indicated that wastewater effluents negatively influenced pH, EC, ammonia, phosphorus, sulphate, boron and chlorine values of Nilüfer Creek.

Akaroğlu and Seferoğlu [13] conducted a study in Sultanhisar town of Aydın province and indicated that irrigation water quality classes varied between C_2S_1 - C_3S_1, canal water quality influenced fruit quality and boron contents of the plants irrigated with these waters were greater than the control plants.

Aregahegn and Zerihun [14] assessed the water quality of Awash River and tributaries through selecting 17 different sampling locations throughout the Awash River and taking water samples four times in a year. For general water quality and suitability for irrigation, pH, EC, SAR, RSC, Na^+, K^+, Ca^{++} + Mg^{++}, CO_3^{2-}, HCO_3^- and Cl^- like several water quality parameters were looked for. Research findings revealed that all quality parameters of the samples taken from Beseka Lake were greater than allowable limits, physicochemical characteristics of Awash River exhibited changes based on different sampling sites and water quality parameters, pH and SAR values only of Beseka Lake and Meteka thermal water were greater than the allowable limits, EC values of Mojo, Wonji, Beseka, Melkasedi, Werer, Ambash, Meteka and Meteka thermal waters exhibited moderate-to-high salinity and these waters had quite a high RSC value. Treatment of industrial effluents was recommended to improve water quality.

II. MATERIALS AND METHODS

Water samples were taken from 20 deep wells opened in agricultural fields of Kütahya – Alayunt village in May, June, July, August and September and soil samples were taken from the fields irrigated with the waters of these deep wells. Kütahya province with a surface area of 11.875 km^2 is located in Western Section of Central Anatolia Region. The province geographically is located between $38^{o}\ 70^{'}$ - $39^{o}\ 80^{'}$ north latitudes and $29^{o}\ 00^{'}$ - $30^{o}\ 00^{'}$ east longitudes. Kütahya province with an altitude of 969 m is surrounded by Bursa province on the north and northwest, Balıkesir province on the west, Bilecik province on the northeast, Afyonkarahisar province on the southeast, Uşak province on the south and Manisa province on the southwest. According to 2018 address-based census, province population is 577.941 people [15]. Kütahya-Centre-Alayunt village is 13 km far from the city center. Geographical position of the research site is presented in Figure 1.

FIGURE 1: Geographical position of research site

The research site has a transitional climate between Aegean, Central Anatolia and Marmora Regions. Temperatures are dominated by Central Anatolia Region and precipitations are dominated by Marmora Region. As a result of terrestrial climate, precipitations are mostly encountered in spring, autumn and winter seasons. Summers are generally dry. Annual average temperature is $10.8^{o}C$. Annual average precipitation is 545.6 mm. The research site has climate characteristics with Kütahya province [15].

Natural plant cover of Kütahya province has characteristics of Mediterranean, Central Anatolia and Marmora Regions. Dry forests are common in the province and they were followed by steppe-type plant populations. Forests are mostly located along the skirts of mountains. Steppe plants are dominant over forest lands and they include red poppy, sagebrush, mountain rhubarb common snapdragon and toy wort species [15].

Kütahya province has a land inventory of 1.187.500 hectares. Of these lands, 64% are constituted by forests (756.776 ha), 7% by pasture and meadows (84.370 ha) and 29% by agricultural lands (346.354 ha) [16].

In Kütahya province, winters are cold and summers are generally dry. Climate and soil structure negatively influence agricultural development. Soils are mostly shallow soils and are not able to store sufficient water with winter and spring precipitations, thus fallow is practiced on significant portion of the lands.

Fallowed rain-fed farming is common in the province. Cereal production is generally practiced in rain-sensitive agriculture method. Therefore, cereals have a significant place in field crops Wheat and barley are the primary cereal crops of the region. Wheat and barley cultivated fields constitute about 40% province agricultural fields.

Kütahya province has limited industrial crop production. Limited irrigation opportunities and undulated land structure are the primary factors limiting the cultivation of industrial crops. Opium poppy and hemp are the traditional industrial crops of the province.

Apart from wheat and barley, cultivated crops include hemp, opium poppy, sunflower, onion, potato, chickpea, beans and sugar beet. Legumes also included in intercropping systems with barley and wheat (cereal in one year, legumes in the other year). Chickpea is the most common legume cultivated in the province. Peach, grape, apple, sour cherry and strawberry-like fruit species are also cultured in the province.

Climate and soil conditions of Kütahya province are quite available for vegetable cultivation, especially for tomato, radish, zucchini, cabbage, lettuce, spinach and leek. Yields are quite high in irrigated lands and bottom lands around the settlements. Vegetable cultivation is mostly practiced for local consumptions, but vegetable cultivated lands are increasing [15].

Irrigation water is supplied from surface and groundwater resources. Farmers receive water from the hydrants placed at the beginning of their lands or from the deep wells within their fields. Mostly drip and sprinkler irrigation methods are preferred in irrigation practices of the farmers.

Water samples were taken from 20 wells already operating in irrigated fields of the research site. Throughout the irrigation season (May – September), water samples were taken 5 times from each well in each month.

Soil samples (6 samples) were taken from irrigated fields during the most intensive irrigation period (July). Disturbed and undisturbed soil samples were taken from 0 – 90 cm soil profile in 30 cm depth segments. Sampled were brought to laboratory and passed through relevant analyses. Soil and water sampling sites are presented in Figure 2.

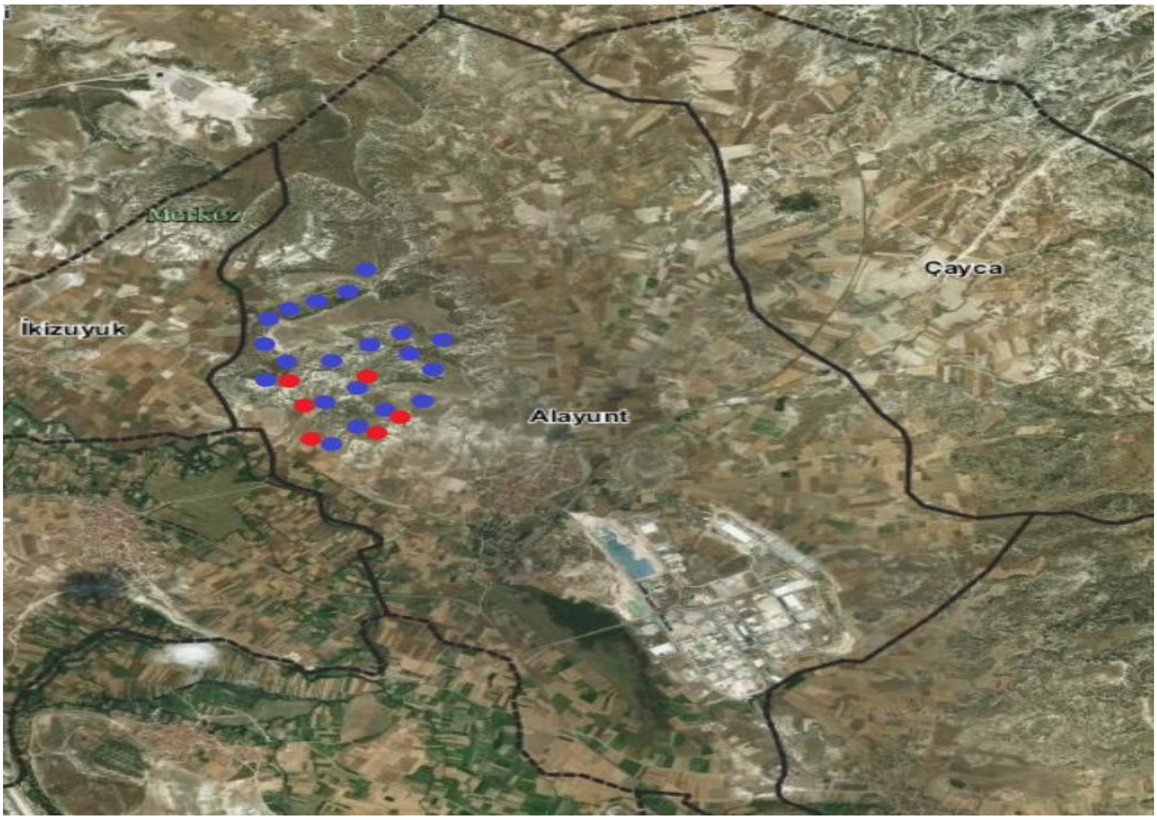

FIGURE 2: Soil and water sampling places (blue color: water sampling points; red color: soil sampling points)

III. RESULTS AND DISCUSSIONS

Water samples were taken from deep wells in each month throughout the irrigation season (May, June, July, August, September).

Electrical conductivity (EC) and pH of water samples taken in May, June, August and September are provided in Table 1 based on well numbers. Irrigation water pH values varied between 7,35 - 8,57 and EC values varied between 563 - 1483 µmhos/cm in May; pH values varied between 7,12 - 7,76 and EC values varied between 713 - 1229 µmhos/cm in June; pH values varied between 7,42 - 8,54 and EC values varied between 585 - 890 µmhos/cm in August; pH values varied between 7,18 - 8,28 and EC values varied between 693 - 834 µmhos/cm in September.

In terms of EC values of irrigation water samples taken in May, the greatest EC values were observed in samples 4 and 5; the samples 1, 6, 11, 14, 16, 17, 18 and 20 had EC values of greater than threshold value (750 µmhos/cm) and the other samples had EC values of lower than threshold value (750 µmhos/cm), thus considered to be more suitable for irrigations. In June, the greatest salinity values were observed in samples 14, 12, 3 and 19 with EC values greater than threshold values (750 µmhos/cm); samples 1, 4 and 20 had EC values of lower than threshold value (750 µmhos/cm), thus considered to be more suitable for irrigation; the other samples had EC values of greater than threshold value (750 µmhos/cm). In August, the greatest salinity values were observed in samples 1, 17 and 20 with EC values of greater than threshold value (750 µmhos/cm); the samples 2, 7, 14, 18 and 19 had EC values of greater than the threshold value (750 µmhos/cm), thus considered to be more suitable for irrigation; the other samples had EC values of greater than the threshold value (750 µmhos/cm). In September, the greatest salinity values were observed in samples 2 and 4 with EC values of greater than the threshold value (750 µmhos/cm); samples 1, 6, 8, 12, 14, 18 and 20 had EC values of lower than the threshold value (750 µmhos/cm), thus considered to be more suitable for irrigation; the other samples had EC values of greater than the threshold value (750 µmhos/cm).

Chemical analysis results of irrigation water samples taken in July are provided in Table 2. Samples pH values varied between 7,41 - 7,89; EC values varied between 709 - 1292 µmhos/cm; boron concentrations varied between 0.11 - 0.1 ppm. In terms of water-soluble anion and cations, it was observed that Mg was dominant cation and HCO_3 was dominant anion. Sodium adsorption ratios (SAR) varied between 0.26 - 0.45, % Na values varied between 5,94 - 7,66 and residual sodium carbonate (RSC) values were not seen. According to US Salinity Lab. Classification systems, water samples taken in July were classified as C_3S_1 and C_2S_1 irrigation waters.

The EC values of irrigation water samples taken in July are presented in Figure 3 based on sample numbers. The greatest salinity values were observed in samples 18, 19, 13, 10 and 17 with EC values of greater than the threshold value (750 µmhos/cm); samples 15, 16 and 20 had EC value of lower than the threshold value (750 µmhos/cm), thus considered to be more suitable for irrigation; the other samples had EC values of greater than the threshold value (750 µmhos/cm).

Boron concentrations of irrigation water samples taken in July are presented in Figure 4 based on sample numbers. Boron concentrations of all samples were lower than the threshold value (0,7 ppm), thus considered to be suitable for irrigation in terms of boron concentration.

Physical analysis results of disturbed and undisturbed soil samples taken from 0-30 cm, 30-60 cm and 60-90 cm soil depths are provided in Table 3. Degree of saturation values varied between 28 - 33,2%, volume-based field capacity (FC) values varied between 29,61 - 35,19%, permanent wilting points (PWP) varied between 11,67 - 28,84% and bulk density values varied between 1,23 - 1,43 g/cm^3. Soils had loamy (L) and clay-loam (CL) textures.

Chemical analysis results of soil samples taken from the research site are provided in Table 4. Soil pH values varied between 7,23 - 7,94, salinity values varied between 638 - 1652 µmhos/cm which were lower than the threshold value (4000 µmhos/cm). Ca was the dominant cation and HCO_3 was the dominant anion. Cation exchange capacity (CEC) values varied between 6,89 - 12,93 me/100 g, exchangeable sodium percentage (ESP) values varied between 4,20 - 13,64 with were lower than the threshold ESP value of 15%. Sample lime contents varied between 4 - 8,14 and boron concentrations varied between 0,25 - 0,13 which were lower than the threshold boron concentration of 4 ppm.

As can be seen in Table 4 and considering the cereal cultivation of the province, soils of the present research site were suitable for cultivation of almost all plant species. Lower boron concentrations of all samples than the threshold value of 4 ppm indicated that there was no risk of boron toxicity in the region, thus almost all plant species could reliably be grown without any risks of boron toxicity.

TABLE 1
EC AND pH VALUES OF THE SAMPLES TAKEN IN MAY, JUNE, AUGUST AND SEPTEMBER

Sample No	May		June		August		September	
	pH	EC x 10^6 µmhos/cm 25 °C	pH	EC x 10^6 µmhos/cm 25 °C	pH	EC x 10^6 µmhos/cm 25 °C	pH	EC x 10^6 µmhos/cm 25 °C
1	7,49	981	7,20	714	7,79	890	8,25	697
2	7,46	602	7,12	815	7,98	599	7,30	834
3	7,54	679	7,19	1171	7,57	786	7,39	809
4	7,39	1483	7,39	713	7,79	773	7,18	830
5	7,57	1286	7,29	877	7,49	801	7,47	787
6	7,50	805	7,51	841	7,57	767	8,28	693
7	8,33	682	7,30	792	8,54	707	7,45	774
8	7,58	667	7,33	791	7,74	787	8,14	729
9	7,96	662	7,48	942	7,87	768	7,50	786
10	7,65	828	7,51	843	7,58	778	7,31	817
11	7,44	786	7,47	942	7,68	791	7,49	789
12	7,75	592	7,35	1174	7,51	803	8,08	744
13	7,66	563	7,61	933	7,53	775	7,42	778
14	7,58	895	7,42	1229	8,19	585	8,19	733
15	8,57	610	7,69	846	7,50	779	7,86	770
16	8,05	969	7,46	905	7,42	804	7,55	786
17	7,83	751	7,40	874	7,56	813	7,77	779
18	7,43	729	7,34	815	8,20	637	8,00	739
19	7,72	628	7,61	1032	7,76	626	7,60	789
20	7,35	832	7,76	743	7,49	812	8,04	716

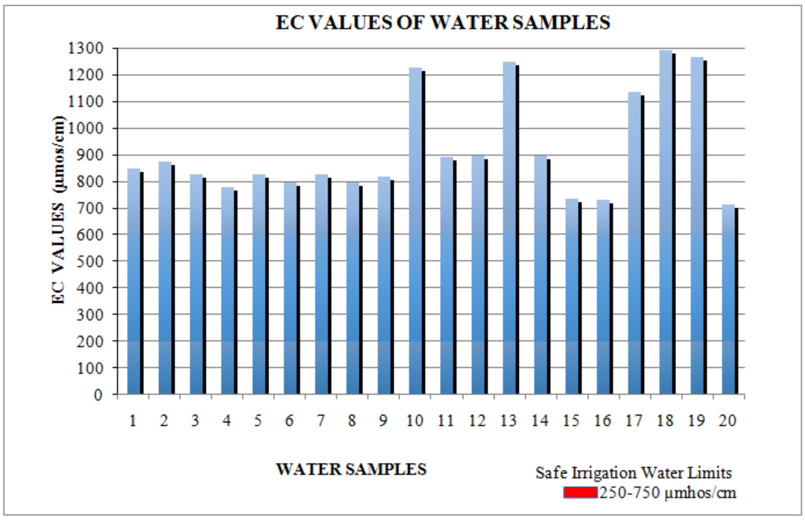

FIGURE 3: EC values of water samples taken in July

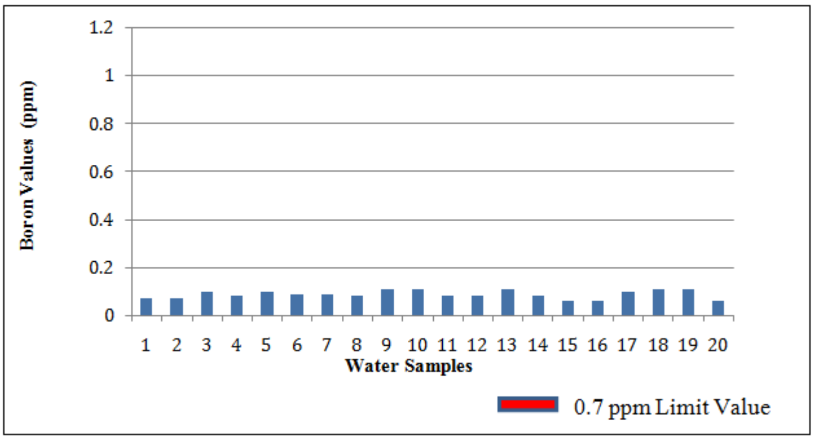

FIGURE 4: Boron concentrations of water samples taken in July

TABLE 2
CHEMICAL ANALYSIS RESULTS OF IRRIGATION WATER SAMPLES TAKEN IN JULY

Sample No	pH	$ECx10^6$ µmhos/cm 25 °C	WATER-SOLUBLE										RSC	SAR	%Na	Irrigation Water Class	Boron (ppm)
			Cations (me/l)					Anions (me/l)									
			Na^+	K^+	Ca^{+2}	Mg^{+2}	Total	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Total					
1	7,53	847	0,69	0,34	3,40	5,76	10,19	-	6,00	1,40	2,80	10,2	-	0,32	6,77	C_3S_1	0,07
2	7,60	872	0,68	0,33	3,69	5,75	10,45	-	5,16	1,60	3,50	10,26	-	0,31	6,50	C_3S_1	0,07
3	7,41	816	0,71	0,29	3,56	4,79	9,35	-	5,32	1,80	2,15	9,27	-	0,34	7,59	C_3S_1	0,1
4	7,58	778	0,64	0,29	3,36	4,56	8,85	-	5,09	1,50	2,35	8,94	-	0,32	7,23	C_3S_1	0,08
5	7,46	815	0,71	0,29	3,56	4,80	9,36	-	5,54	2,0	1,15	9,49	-	0,34	7,58	C_3S_1	0,1
6	7,49	796	0,68	0,28	3,50	4,71	9,17	-	5,92	1,30	2,00	9,22	-	0,33	7,41	C_3S_1	0,09
7	7,42	815	0,71	0,29	3,56	4,80	9,36	-	4,94	1,50	2,70	9,14	-	0,34	7,58	C_3S_1	0,09
8	7,54	797	0,65	0,30	4,0	5,86	10,81	-	4,56	1,70	3,75	10,01	-	0,29	6,01	C_3S_1	0,08
9	7,67	808	1,06	0,5	5,88	7,76	15,2	-	8,13	3,86	3,10	15,09	-	0,40	6,97	C_3S_1	0,11
10	7,64	1226	1,04	0,48	5,65	7,66	14,83	-	7,37	3,28	3,95	14,6	-	0,40	7,01	C_3S_1	0,11
11	7,89	892	0,64	0,30	3,98	5,84	10,76	-	5,85	2,10	2,80	10,75	-	0,28	5,94	C_3S_1	0,08
12	7,69	897	0,65	0,30	3,96	5,83	10,74	-	4,78	2,50	3,36	10,64	-	0,29	6,05	C_3S_1	0,08
13	7,62	1245	1,06	0,49	5,88	7,76	15,19	-	6,91	3,20	4,70	14,81	-	0,40	6,97	C_3S_1	0,11
14	7,83	893	0,65	0,30	4,02	5,88	10,85	-	5,39	2,16	3,00	10,55	-	0,29	5,99	C_3S_1	0,08
15	7,64	730	0,54	0,25	3,21	4,46	8,46	-	5,09	1,10	2,50	8,69	-	0,27	6,38	C_2S_1	0,06
16	7,54	731	0,54	0,25	3,22	4,47	8,48	-	3,80	1,25	3,25	8,3	-	0,27	6,36	C_2S_1	0,06
17	7,81	1134	1,03	0,47	4,79	7,33	13,62	-	6,08	2,67	4,83	13,58	-	0,41	7,56	C_3S_1	0,1
18	7,45	1292	1,2	0,50	6,04	7,91	15,65	-	8,66	3,10	3,95	15,71	-	0,45	7,66	C_3S_1	0,11
19	7,58	1265	1,08	0,50	5,88	7,81	15,27	-	7,06	2,70	4,50	14,26	-	0,41	7,10	C_3S_1	0,11
20	7,63	709	0,51	0,24	3,13	4,31	8,19	-	3,26	2,55	2,20	8,01	-	0,26	6,22	C_2S_1	0,06

TABLE 3
SOIL PHYSICAL CHARACTERISTICS OF THE RESEARCH SITE

Soil Sampling		Saturation (%)	FC (Volume, %)	PWP (Volume, %)	Available Water	Bulk Density (g/cm^3)	Soil Texture			
Plot No	Depth (cm)						Sand %	Clay %	Silt %	Texture
1	0-30	33,2	30,80	16,10	14,70	1,36	38,70	26,30	35,00	L
	30-60	30,8	29,90	16,75	13,15	1,39	41,20	26,30	32,50	L
	60-90	30,4	29,61	16,56	13,05	1,43	38,70	23,80	37,50	L
2	0-30	30,10	35,04	18,93	16,11	1,34	33,70	26,30	40,00	L
	30-60	31,4	35,19	20,06	15,13	1,35	38,70	26,30	35,00	L
	60-90	29,10	33,59	28,84	4,75	1,37	33,70	28,80	37,50	CL
3	0-30	30,12	30,01	18,45	11,56	1,34	38,70	28,80	32,50	CL
	30-60	28,4	30,67	18,65	12,02	1,35	41,20	31,30	27,50	CL
	60-90	30,8	32,00	11,67	20,33	1,37	41,20	31,30	27,50	CL
4	0-30	29,6	32,97	19,28	13,69	1,30	38,70	23,80	37,50	L
	30-60	32,2	33,20	19,60	13,60	1,32	41,20	28,80	30,00	CL
	60-90	27,4	32,33	19,77	12,56	1,39	41,20	23,80	35,00	L
5	0-30	31	33,89	19,68	14,21	1,29	31,20	33,80	35,00	CL
	30-60	29,8	33,71	20,11	13,60	1,30	33,70	31,30	35,00	CL
	60-90	33	34,58	20,09	14,49	1,36	38,70	31,30	30,00	CL
6	0-30	28	31,97	20,03	11,94	1,31	43,70	26,30	30,00	L
	30-60	29	32,32	20,22	12,10	1,33	43,70	23,80	32,50	L
	60-90	28,10	31,53	20,56	10,97	1,37	46,20	23,80	30,00	L

TABLE 4
SOIL CHEMICAL CHARACTERISTICS OF THE RESEARCH SITE

Soil Sampling		pH	EC x 10^6 µmhos/cm 25 °C	Water- Soluble										CEC (me/100gr)	Exchangable Cations			ESP (%)	Lime (%)	Boron (ppm)
				Cations (me/L)					Anions (me/L)											
Plot No	Depth (cm)			Na^+	K^+	Ca^{+2}	Mg^{+2}	Toplam	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Toplam		Na^+	K^+	$Ca^{+2}+Mg^{+2}$			
1	0-30	7,47	1077	0,45	1,22	9,74	2,20	13,61	-	7,44	1,12	4,97	13,53	8,27	0,62	2,86	4,89	7,49	4	0,14
	30-60	7,48	996	0,47	1,12	8,90	2,15	12,64	-	6,30	4,06	2,35	12,71	9,12	1,00	2,75	5,56	10,96	4	0,13
	60-90	7,54	840	0,47	1,07	8,84	2,10	12,48	-	6,00	2,06	3,37	11,43	6,89	0,67	2,02	4,47	9,7	4	0,13
2	0-30	7,53	1334	0,59	2,11	12,85	2,83	18,38	-	11,55	2,84	3,50	17,89	10,08	1,34	3,88	5,76	13,29	8,14	0,25
	30-60	7,58	1652	0,58	2,18	12,68	2,82	18,26	-	10,26	2,36	5,00	17,62	9,41	0,76	3,58	6,92	8,07	6,14	0,25
	60-90	7,72	1359	0,56	2,11	12,19	2,73	17,59	-	9,42	4,84	3,27	17,53	12,93	1,28	4,13	8,04	9,89	6,4	0,24
3	0-30	7,38	1243	0,51	1,96	10,20	2,36	15,03	-	9,88	2,34	2,70	14,92	8,53	0,43	3,08	4,04	5,04	6,18	0,15
	30-60	7,54	827	0,52	1,72	9,98	2,21	14,43	-	8,20	5,66	2,57	16,43	8,49	1,00	3,16	3,28	11,77	6,4	0,14
	60-90	7,84	1096	0,54	1,77	10,33	2,27	14,91	-	7,22	1,2	5,49	13,91	9,07	0,64	3,32	4,52	7,05	6	0,14
4	0-30	7,46	1290	0,41	3.00	10,91	2,47	16,79	-	12,61	0,6	3,45	16,66	9,01	0,72	3,16	5,34	7,9	6	0,2
	30-60	7,38	1073	0,42	3,05	11,20	2,51	17,18	-	13,37	1,4	2,44	17,21	9,03	0,68	4,02	4,98	7,53	6,2	0,2
	60-90	7,23	1259	0,41	2,90	10,51	2,42	16,24	-	10,10	1,8	4,31	16,21	8,36	0,61	3,42	4,72	7,29	6,4	0,19
5	0-30	7,78	712	0,50	2,30	11,18	2,55	16,53	-	9,27	1,6	5,36	16,23	10,55	1,44	4,80	6,80	13,64	6,12	0,17
	30-60	7,64	685	0,52	2,19	11,20	2,53	16,44	-	9,5	2,54	4,24	16,28	11,99	1,51	4,12	5,98	12,59	6,4	0,17
	60-90	7,62	638	0,50	2,20	11,28	2,55	16,53	-	8,89	2,6	4,49	15,98	11,26	1,30	4,70	6,84	11,54	4,14	0,17
6	0-30	7,73	737	0,48	3,04	12,72	2,69	18,93	-	9,65	3,54	5,23	18,42	9,76	0,41	3,72	4,85	4,20	6,12	0,24
	30-60	7,94	670	0,45	2,86	12,49	2,64	18,44	-	9,88	3,46	5,00	18,34	7,79	0,97	3,17	4,66	12,45	6,4	0,24
	60-90	7,88	608	0,37	2,53	2,16	2,62	7,68		5,09	4,68	2,01	11,78	11,25	1,39	3,80	6,92	12,35	6,10	0,24

IV. CONCLUSION

Following conclusions could be drawn from the findings of the present study conducted to assess irrigation water quality and salinity-alkalinity of the agricultural fields of Kütahya-Alayunt village:

a) The samples with salinity values of lower than the threshold value (750 µmhos/cm) were classified as **moderately saline (C_2),** thus could reliably be used in irrigation of agricultural fields. The other water samples with salinity values of greater than the threshold value (750 µmhos/cm) were classified as **highly saline (C_3),** thus could be be used in irrigation of salt-resistant plant species and special measures should be taken for salinity control. Irrigation water pH values varied between 7,12 - 8,57 and EC values varied between 563 - 1483 µmhos/cm. Based on salinity-alkalinity values, water samples were classified as C_2S_1 (moderately saline – low alkaline) and C_3S_1 (highly saline – low alkaline).

b) In terms of water-soluble anion and cations, it was observed that Mg was the dominant cation and HCO_3 was the dominant anion. Sodium Adsorption Ratios (SAR) varied between 0,26 - 0,45, % Na values varied between 5,94 - 7,66 and boron concentrations varied between 0,11 - 0,1 ppm. Boron concentrations of all samples were lower than the threshold value of 0,7 ppm specified for irrigation waters. Such a case revealed that there was no risk of boron toxicity in experimental fields.

c) Soil pH values varied between 7,23 - 7,94, EC values varied between 638 - 1652 µmhos/cm, cation exchange capacity (CEC) values varied between 6,89 - 12,93 me/100g, exchangeable sodium percentages (ESP) varied between 4,20 - 13,64%, lime contents varied between 4.0 - 8,14% and boron concentrations varied between 0,25 - 0,13 ppm, which were lower than the threshold value of 4 ppm specified for soils.

d) Soil textures were identified as loamy (L) and clay-loam (CL). Soil degree of saturation values varied between 28,0 - 33,2 and bulk densities varied between 1,23 - 1,43 g/cm^3.

e) Exchangeable sodium percentage (ESP) of all samples was lower than the threshold value of 15% specified for soils.

f) Although irrigation water samples were generally classified as highly saline (C_3), salinity was not encountered in soils of the research site since sufficient salt accumulation with irrigation hasn't been reached, yet.

RECOMMENDATIONS

a) There is a need for development of water resources in the research site to prevent future salinity problems (as it was in GAP and KOP projects). In this sense, more suitable irrigation waters in terms of quality should be supplied.

b) Drainage systems should be developed to prevent potential salinity problems.

c) Soils should be enriched in organic matter and soil tillage systems should be emphasized.

d) Measures should now be taken to prevent potential salinity problems. In this sense, soil reclamation and leaching practices should be emphasized.

e) Proper irrigation methods should be selected to prevent loss of yield and quality. Because of leaching function, sprinkler irrigation should be preferred in places with limited water resources and basin (ponding) irrigation should be preferred in places with sufficient water resources.

f) Farmers should be trained on efficient and conscious water use in irrigation by universities or agricultural organizations.

Note: This study was derived from the Master Thesis of Gülşah KAPLAN.

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