

EVALUATION OF IRRIGATION WATER QUALITY OF AKSARAY REGION BY USING GEOGRAPHIC INFORMATION SYSTEM

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Abstract: In this study, the quality of irrigation water was determined in Aksaray region which is one of the most important agricultural lands of Turkey, the facts causing pollution were specified and the precautions that should be taken were discussed. Within the scope of this study, 38 samples were taken from the water of 24 wells, 4 dams, 9 ponds and 1 source water. In order to use the data more effectively, irrigation water quality index map of Aksaray region including the results of the samples (EC, SAR, B, Cl⁻, NO₃⁻, HCO₃⁻ and pH) was prepared by using Geographic Information System (GIS). According to irrigation water quality index map, all surface water sources were found to be suitable for irrigation with high and medium irrigation water quality index. EC, SAR, Cl⁻, HCO₃⁻ values were found as high in Acıpinar well and Aratol well regions whereas EC and Cl⁻ values were high in Taspınar well region. It was determined that underground water sources have low irrigation water quality index value along in the range of Taspınar region and Tuz Lake whereas they have generally medium irrigation water quality index value. The soil being heavy-texture and salty structure in the region and the level of ground water being high were caused by lack of adequate drainage system. For this reason, good and adequate drainage system should be configured in order to provide no increase in salt accumulation in the soil, to get an opportunity for more appropriate land use and to increase the yield per unit area.

Keywords: Aksaray region, environmental pollution, geographic information system, irrigation water quality, seasonal variation.

1. INTRODUCTION

Environmental pollution caused by rapid increase in the population of the world, urbanization, industrialization and unaware excess usage of pesticides and fertilizers in agricultural areas impaired the quality of water sources and water sources became almost receiving environments where wastes are discharged (Gündoğdu & Kocatas, 2006). Beyond important economical losses caused by pollution in water sources, it directly may threaten the lives of living things and human beings depending on the type and dense of pollution (GDEPRSDA, 2005). For example, Kalyoncu et al., (2008) determined that the variety of epilithic algae changed in parallel with the quality of water. In

order to provide the continuity of ecological balance, the presence and quality of water are very important. It's necessary to make water quality controls at determined periods regularly for the protection and taking under control of the ecosystems (rivers, lakes, wetlands, etc.) fed by water sources. Therefore, researches on water quality monitoring and wastewater treatment are increasing every day (Akkoz et al., 2009; Ferenczi & Balog, 2010; Dragicevic et al., 2010; Parvulescu & Hamchevici, 2010; Kalıpcı, 2011; Ozdemir et al., 2012; Pop et al., 2012). The qualities of water should be determined, the facts causing the pollution should be indicated and necessary precautions should be taken to minimize the pollution (Karadavut et al., 2011). Computer-aided data analysis and visualization tools

have an important role in the studies of protection, development and management of water sources. Especially Geographic Information Systems (GIS) have been recently used commonly for this aim all over the world (Ozgen & Cakicioglu, 2009). By means of these analysis methods, easy to use data sources are formed, the factors affecting the water quality are defined and strategies appropriate for the management of water sources are developed (Simeonov et al., 2003; Mendiguchia et al., 2004; Lambrakis et al., 2004; Singh et al., 2005).

For this reason, the samples taken from 38 measurement stations including ponds, dams and wells in Aksaray irrigation water basin in 2008 and 2009 by using Geographic Information System (GIS) were evaluated, their irrigation water qualities were determined and the facts causing pollution were specified. The maps including the results of analysis belonging to irrigation water quality parameters (EC, SAR, B, Cl⁻, NO₃⁻, HCO₃⁻ and pH) were prepared. Irrigation water quality index map of Aksaray region belonging to irrigation period was prepared by combining these maps.

2. MATERIALS AND METHODS

2.1. Research area

Aksaray city which was selected as a study area is between 30 – 35° east longitudes and 38 – 39° north latitudes (Fig. 1). In our study area covering Aksaray region, 24 wells, 4 dams, 9 ponds and 1 source water as well as the wells present along this area are the main sources for drinking, potable and irrigation water of the

region. Since the rainfall is low and most of the region is the private environmental protection region, this increases the value of water potential one more fold.

2.2. Analysis of data

In Aksaray water basin, 38 sample stations (Table 1) were determined and the samples taken in three-month periods between February 2008 and August 2009 were analyzed in the laboratory. The sample analysis were performed according to APHA/AWWA/WEF (2005) and the methods used in the measurements are given in Table 2. Important parameters for irrigation water quality index such as electrical conductivity (EC), Sodium Adsorption Rate (SAR), B, Cl⁻, NO₃⁻, HCO₃⁻ and pH values were found. Its applicability (high, medium, low) in terms of irrigation water quality was obtained by multiplying significance degree of analysis results according to values in the range with application rate of this. Each parameter was classified within itself after taking the averages of the data and applied to the whole region by interpolations with 100x100 meter distances in ArcGIS 9.1 programme. The evaluations of irrigation water quality classifications were carried out according to maximum limit values of irrigation water quality parameters published by Ministry of Environment and Forestry Water Pollution Control Regulations (Republic of Turkey Ministry of Environment and Forest, 1991) and FAO (Food and Agricultural Organization) (FAO, 1994).

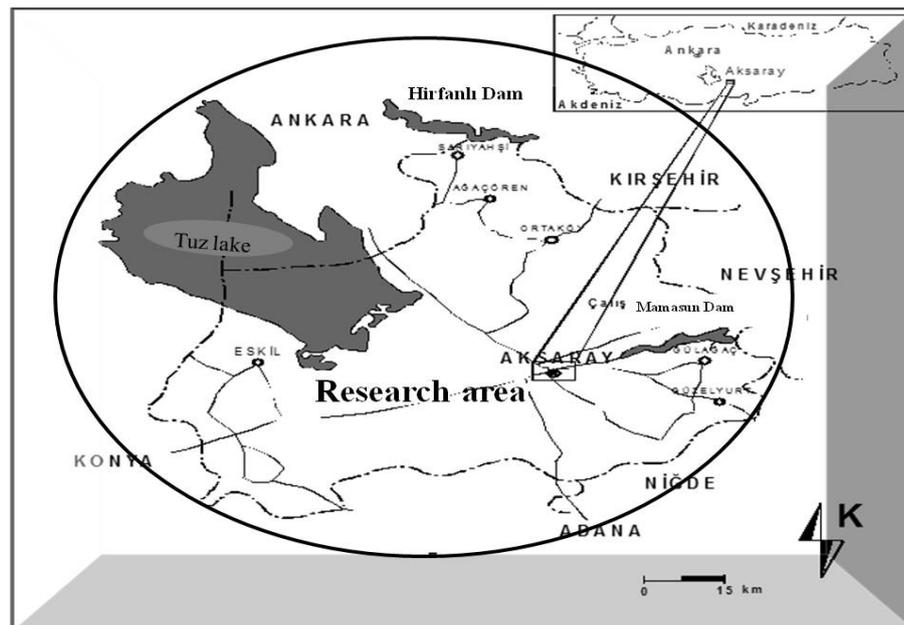


Figure 1. Site location map of working site (Adapted from Karadavut et al., 2011)

Table 1. Sampling points and their coordinates

Sample points	Coordinates	Sample points	Coordinates
Aksaray Center		Eskil	
1.Taspinar well	36589001 E – 4231790 N	21.Esmekaya well	36539839 E – 4231453 N
2.Hamidiye well	36587245 E – 4237957 N	22.Yazır well	36537881 E – 4241964 N
3.Aratal well	36584161 E – 4245943 N	23.Sagsak well	36530656 E – 4239916 N
4.Yenikent well	36566388 E – 4238525 N	24.Günesli well	36544514 E – 4224390 N
5.Yesilova well	36578128 E – 4259053 N	Ortaköy	
6.Altinkaya well	36568789 E – 4273951 N	25.Sarıkaraman well	36601646 E – 4290860 N
7.Acıpinar well	36574845 E – 4264977 N	26.Harmandalı well	36582668 E – 4308370 N
8.Agzıkarahan well	36599671 E – 4255943 N	27.Balcı well	36595982 E – 4287052 N
9.Bağlıkaya	36586446 E – 4266827 N	28.Ciftevi pond	36588728 E – 4299159 N
10.Kutlu well	36575471 E – 4236973 N	29.Bogazköy pond	36578597 E – 4312061 N
11.Sağlık well	36593662 E – 4240112 N	30.Balcı pond	36592177 E – 4284280 N
12.Sevincli well	36597701 E – 4246689 N	31.Balcı Kepir pond	36597267 E – 4284714 N
13.Mamasın dam	36591762 E – 4248127 N	32.Bozkır pond	36595440 E – 4291118 N
14.Helvadere pond	36605894 E – 4229840 N	Sarıyahsi	
Güzelyurt		33.Hirfanlı dam	36576153 E – 4321902 N
15.Selime well	36610749 E – 4241497 N	34.Sarıyahsi pond	36572387 E – 4314279 N
16.Dogantarla well	36604559 E – 4244404 N	Gülagac	
17.Güzelyurt pond	36618783 E – 4236848 N	35.Gülagac well	36617649 E – 4251972 N
18.Kırkgöz source water	36615199 E – 4230542 N	36.Gülagac pond	36619829 E – 4250539 N
Agacören		37.Karasu-dam entry	36056520 E – 4249752 N
19.Agacoren well	36580628 E – 4303782 N	38.Melendiz-dam entry	36060920 E – 4248224 N
20.Eski Ahırlı well	36570391 E – 4285971 N		

Table 2. Water quality parameters and methods for their measurements

Parameters	Analytical methods
Temperature (°C)	Digital thermometer
pH	pH meter
Conductivity (µS/cm)	Electrometric
Total Dissolved Solids TDS (mg/L)	Electrometric
Salinity (%)	Electrometric
Turbidity (NTU)	Turbidimeter
Total Alkalinity (mg/L)	Titration method
Total hardness (mg/L)	Titration method
Nitrate-N (mg/L)	Spectrophotometric
Ammonium-N (mg/L)	Spectrophotometric
Chloride (mg/L)	İon chromatography
Sulfate (mg/L)	İon chromatography
Total Organic Carbon (TOC) (mg/L)	Catalytic oxidation
Total Nitrogen (TN)(mg/L)	Catalytic oxidation
Ca (mg/L)	Spectrometric
Mg (mg/L)	Spectrometric
K (mg/L)	Spectrometric
Na (mg/L)	Spectrometric
Bicarbonate (mg/L)	Calculation (4500 CO ₂ D APHA-AWWA-WEF, 2005)

3. FINDINGS

When electrical conductivity (EC) values belonging to irrigation period were investigated, it was determined that EC values generally varied between 150 and 1470 µS/cm in 2008 whereas they changed between 180 and 1500 µS/cm in 2009. According to irrigation water standards determined by FAO (1994), there was no inconvenience for using these waters. As it can be seen in Figure 2,

there was a great increase in EC values along in the range of Tuz Lake. However, using these waters as irrigation water was found as inconvenient by FAO (1994). High EC value especially observed in Acıpinar and Aratal regions was caused by flow to the sources in the wells which were opened in an uncontrolled way in these regions and where excess pumping was done from Tuz Lake and by domestic waste discharges from settlements in this region to the receiving environment in an uncontrolled way.

In the region, predominantly barley, wheat, sugar pulp, fruit and vegetable productions are carried out. In Table 3, the threshold values are given in terms of EC values belonging to some plants produced. According to this, it was determined that EC values of some plants produced in most of the region were below threshold values. EC values in 2008 and 2009 were below threshold value just for barley, wheat and sugar pulp for Hirfanlı Dam among underground water sources and surface water sources in the region within the range of Tuz Lake. In the case of using these sources for the production of fruits and vegetables, it was determined that they won't be suitable in terms of irrigation water quality because of EC values being higher than threshold values.

The results of analysis of sampling points are given in Table 4. When they were investigated in terms of SAR (Sodium Adsorption Rate) values, it was determined that SAR values were generally between 0 and 3.5 in 2008 and varied between 0 and 4.0 in 2009. According to irrigation water standards specified by FAO (1994), there was no inconvenience for using them in irrigation. As it can be seen in Figure 3, the underground water source in Acıpinar region was found inconvenient for using in irrigation since its SAR values were higher than limit values. Ca^{++} and Mg^{++} ions present in the medium precipitate because of high value of HCO_3^- ion and Na^+ ions dominate in the medium. Thus, increase in SAR value damages the physical structure of the soil and negatively affects ion distribution equilibrium necessary for plant development and amount of its water capacity.

When results of pH analysis in 2008 and 2009 were investigated according to FAO (1994) standards, it was approved for irrigation since pH values were generally within limit values. It was determined that the highest pH value was in Güzelyurt pond region (Fig. 4).

According to FAO (1994) standards, Acıpinar, Aratol and Taspınar regions had the highest Cl^- values which were above limit value for irrigation (Fig. 5). Generally Cl^- values varied between 8 and 157 mg/L in 2008 and between 8 and 173 mg/L in 2009 which showed parallelism with EC distribution. Along the range of Tuz Lake, there was an increase in HCO_3^- values and the highest values were observed in Aratol and Acıpinar regions (Fig. 6). Since HCO_3^- values generally varied between 95 and 561 mg/L in 2008 and between 90 and 577 mg/L in 2009, it was approved for irrigation.

The irrigation period in terms of NO_3^- distribution in 2008 and 2009 generally varied between 0 and 10 mg/L which was below limit value for irrigation according to FAO (1994) standards. The highest nitrate value was observed in Balçı well region (Fig. 7).

When boron (B) values of irrigation period were considered, it was observed that boron values generally varied between 0 and 0.70 mg/L in 2008 and between 0 and 0.75 mg/L in 2009. Boron values varied between 0.7 and 3.3 mg/L while going from Aratol its environment to the range of Tuz Lake and its highest value was observed in Aratol region. Simsek and Gündüz (2007) indicated that boron values were high in the regions especially where Na^+ ions were also high and had a high correlation with SAR values. When B concentration distribution (Figure 8) and SAR distribution (Figure 3) of the region were considered, similarity of both distributions confirmed this relationship.

Irrigation water quality index map of irrigation period in Aksaray region was obtained by combination of all these maps including irrigation water quality parameters (Fig. 9).

Table 3. Salt tolerances of some plants (Kotuby et al., 1997)

<i>Plant Variety</i>	<i>Threshold value (EC $\mu S/cm$)</i>
Barley	5.300
Clover	1.300
Wheat	4.000
Sugar beet	4.700
Lettuce	900
Tomatoes	1.700
Corn	1.100
Apple	1.000
Peach	1.100

Table 4. The results of analysis of sampling points

Sample points	Parameters								
	EC (µS/cm)	TDSM (mg/L)	NO ₃ ⁻ (mg/L)	Cl ⁻ (mg/L)	SO ₄ ⁼ (mg/L)	B (mg/L)	SAR	RSC (meq/L)	Class
Aksaray Center									
1	1.291	821	4.67	269.20	11.99	1.73	5.17	0.29	C ₃ S ₂
2	647	418	13.40	67.15	68.60	0.69	1.33	-1.73	C ₂ S ₁
3	2.081	1.543	1.88	364.05	74.44	3.17	6.15	6.02	C ₃ S ₂
4	651	486	12.51	98.25	58.75	1.02	1.80	-2.04	C ₂ S ₁
5	1.240	803	2.75	176.75	42.45	2.14	3.81	1.85	C ₃ S ₁
6	1.444	963	8.98	253.55	147.12	1.01	3.46	-1.45	C ₃ S ₁
7	2.918	2.026	25.60	324.90	361.91	1.44	9.99	10.27	C ₄ S ₃
8	462	307	11.79	23.10	21.57	0.16	0.58	-0.80	C ₂ S ₁
9	1.276	877	7.02	126.50	188.82	0.96	2.99	-0.58	C ₃ S ₁
10	592	419	12.93	63.45	81.13	0.41	0.79	-2.98	C ₂ S ₁
11	767	484	1.27	38.75	34.67	0.19	1.00	-1.46	C ₃ S ₁
12	540	352	12.28	12.35	332.06	0.19	0.62	-0.48	C ₂ S ₁
13	554	319	0.77	56.25	30.38	0.91	1.84	0.40	C ₂ S ₁
14	310	167	0.09	21.55	16.86	0.06	0.95	-0.31	C ₂ S ₁
Güzelyurt									
15	362	217	4.05	17.75	15.34	0.14	1.00	0.36	C ₂ S ₁
16	395	250	11.79	17.15	39.76	0.14	0.54	-0.76	C ₂ S ₁
17	341	194	0.01	27.10	19.06	0.09	0.96	0.43	C ₂ S ₁
18	186	90	1.84	6.05	15.57	0.01	0.46	-0.28	C ₁ S ₁
Agacören									
19	346	229	7.27	18.60	10.82	0.05	0.39	-0.21	C ₂ S ₁
20	913	550	7.80	59.95	78.55	0.27	1.01	-1.79	C ₃ S ₁
Eskil									
21	1.002	676	1.96	132.90	57.64	0.39	1.78	-1.48	C ₃ S ₁
22	1.220	803	2.77	155.30	102.12	1.02	2.15	-1.70	C ₃ S ₁
23	1.104	770	2.45	116.65	71.12	0.66	1.49	-1.37	C ₃ S ₁
24	841	575	1.99	97.70	46.70	0.37	1.57	-0.22	C ₃ S ₁
Ortaköy									
25	913	612	5.59	55.80	205.77	0.44	1.90	-1.64	C ₃ S ₁
26	677	458	3.04	44.05	55.10	0.12	0.66	-1.03	C ₂ S ₁
27	738	574	22.50	57.20	82.41	0.17	0.87	-1.22	C ₂ S ₁
28	435	251	0.04	28.80	30.19	0.09	0.83	-0.74	C ₂ S ₁
29	448	271	0.03	16.60	29.94	0.11	0.95	0.42	C ₂ S ₁
30	191	107	0.01	6.55	13.52	0.02	0.46	-0.06	C ₁ S ₁
31	234	156	0.01	8.45	33.27	0.04	1.00	-0.27	C ₁ S ₁
32	897	632	0.12	161.80	39.89	0.24	0.42	0.38	C ₃ S ₁
Sarıyahşi									
33	1.394	919	0.22	243.45	416.56	0.39	4.52	-5.63	C ₃ S ₁
34	459	258	0.01	16.40	42.38	0.11	1.12	-0.35	C ₂ S ₁
Gülagac									
35	790	518	9.77	45.40	41.19	0.45	1.14	0.24	C ₃ S ₁
36	580	379	1.61	29.15	14.66	0.61	1.12	0.76	C ₂ S ₁
37	773	484	2.35	79.55	33.22	1.48	2.12	0.83	C ₃ S ₁
38	694	471	0.50	53.20	10.13	1.71	2.00	-1.64	C ₂ S ₁

TDSM
: Total

Dissolved Solid Material, RSC: Residual Sodium Carbonate, SAR: Sodium Adsorption Rate

4. RESULTS

The following evaluations were made by taking Water Pollution Control Regulations (Republic of Turkey Ministry of Environment and

Forest, 1991) irrigation water quality classification and FAO (1994) irrigation water quality maximum limit values into consideration.

When it was evaluated in terms of Electrical conductivity (EC) and SAR, irrigation water quality

classes were not affected from seasonal variations and this difference was found as insignificant in terms of statistics. When EC and SAR values of irrigation period (Summer) were investigated, surface waters

were generally IInd class and underground waters were IInd and IIIrd class in terms of EC whereas both surface and underground water sources had Ist class water quality property in terms of SAR.

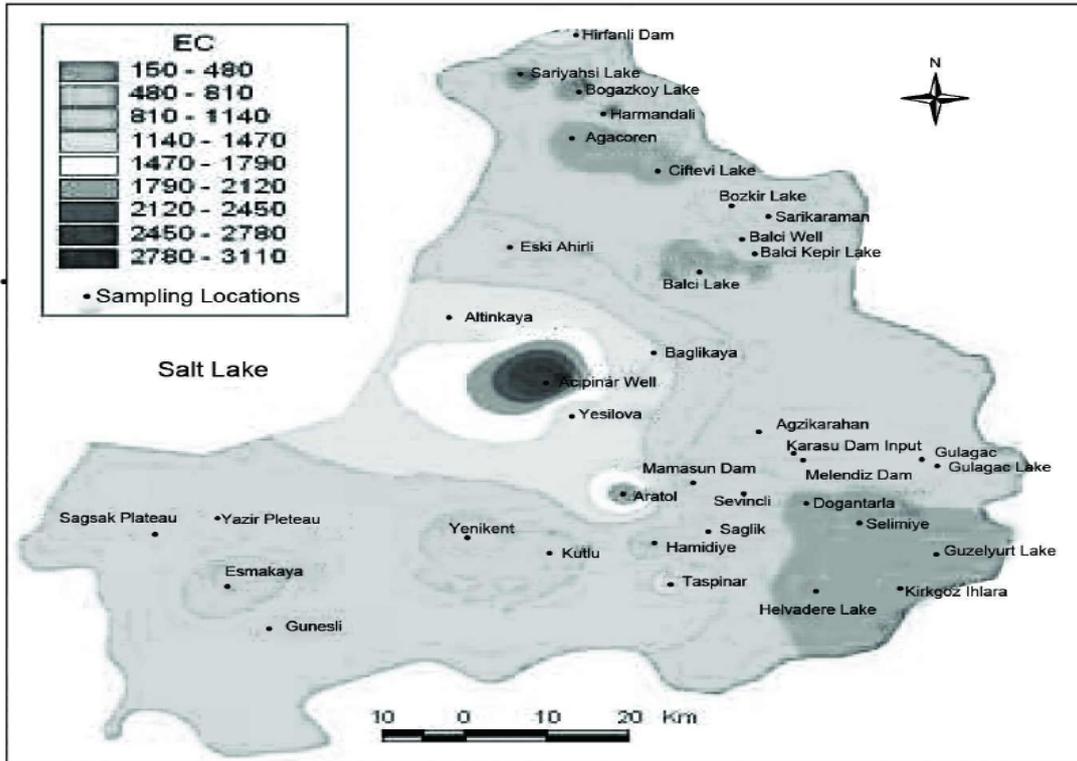


Figure 2. EC ($\mu\text{S}/\text{cm}$) distribution of irrigation period in Aksaray region

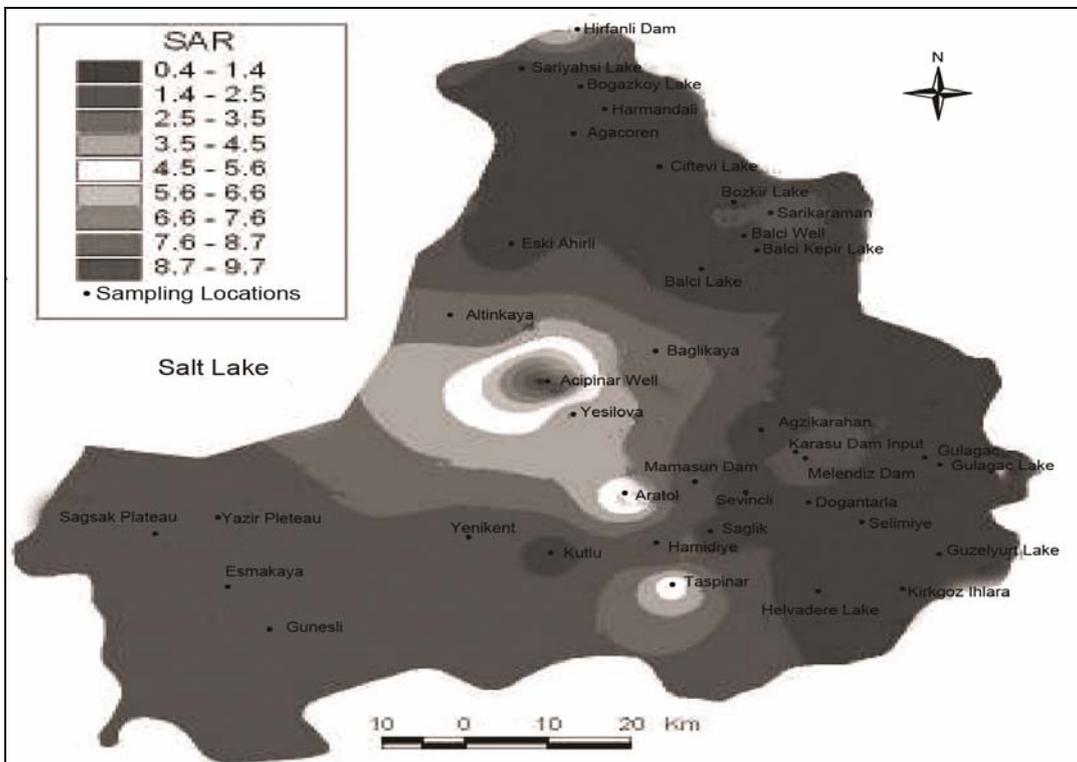


Figure 3. SAR distribution of irrigation period in Aksaray region

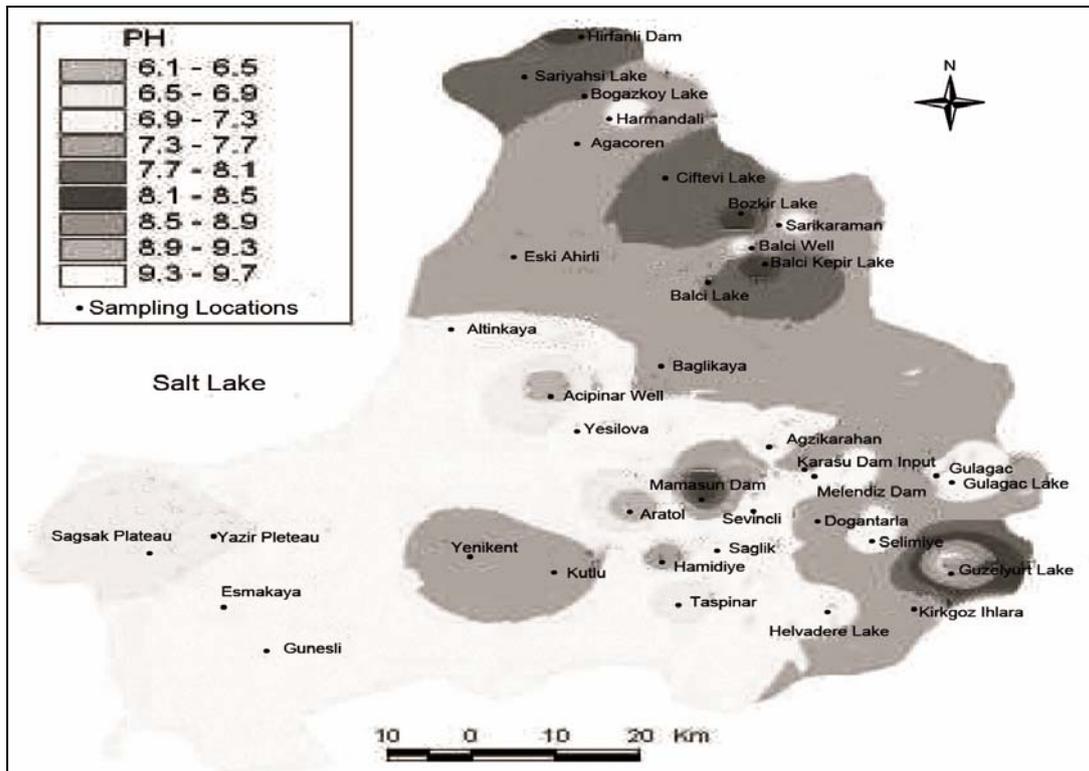


Figure 4. pH distribution of irrigation period in Aksaray region

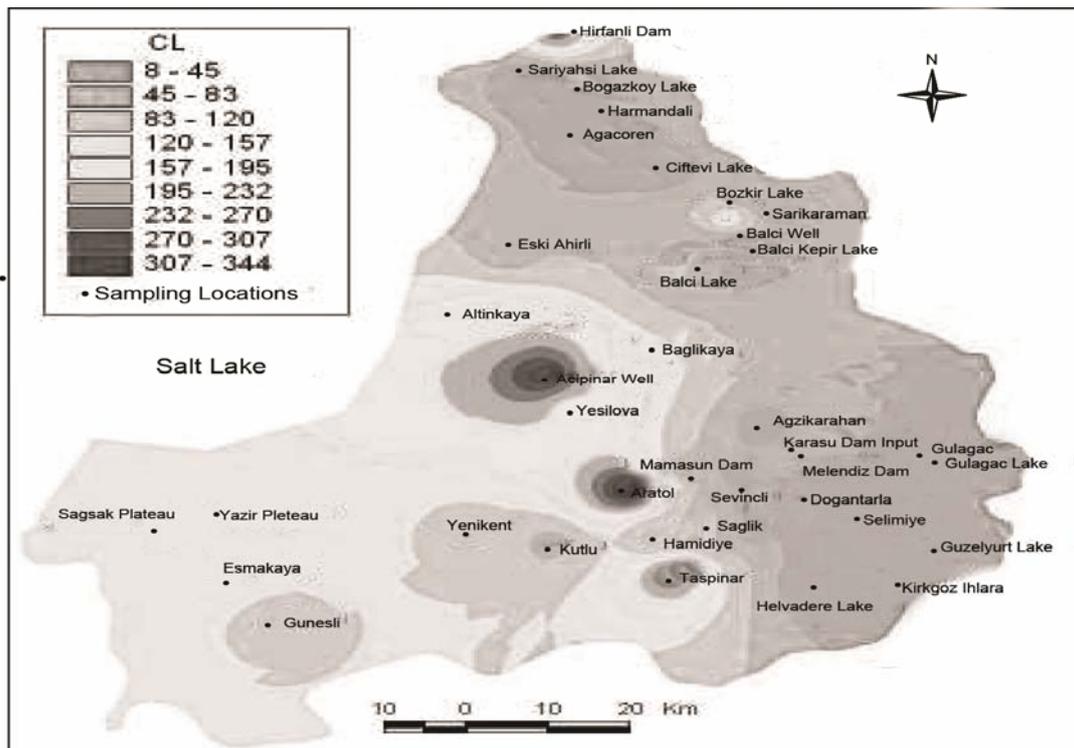


Figure 5. Cl (mg/L) distribution of irrigation period in Aksaray region

Especially low values of SAR substantially decreased SAR caused by bicarbonate ions having high concentration values. Since the soil of the region has a heavy texture and salty-sodium structure, high ground water level and inadequate

drainage system, it restricts the usage of underground water having high EC values in irrigation. When anion and cation distributions were investigated, surface and underground water sources had generally carbonated and sulphated water class

property. Although nitrate (NO_3^-) is generally not desired in irrigation water due to its fertilizing values, excess amount of nitrate decreases the permeability of the soil.

There was no seasonal variation in terms of nitrate (NO_3^-) and generally surface water sources had Ist class and underground water sources had Ist and IInd class property of irrigation water quality.

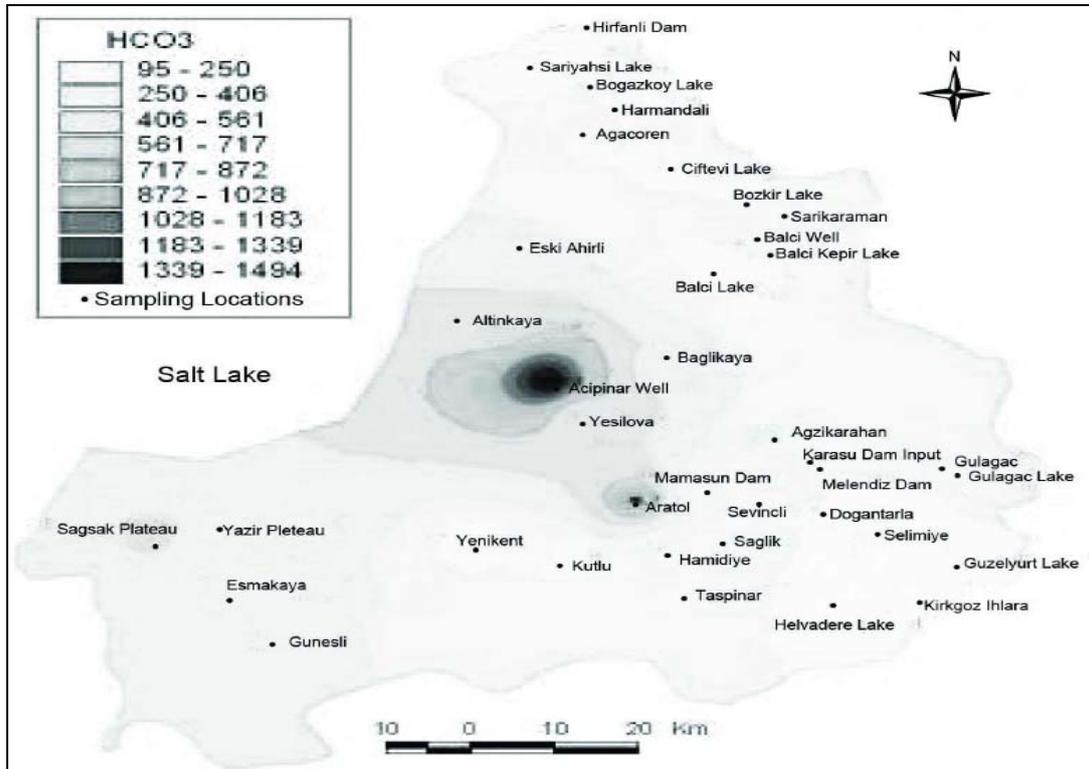


Figure 6. HCO_3^- (mg/L) distribution of irrigation period in Aksaray region

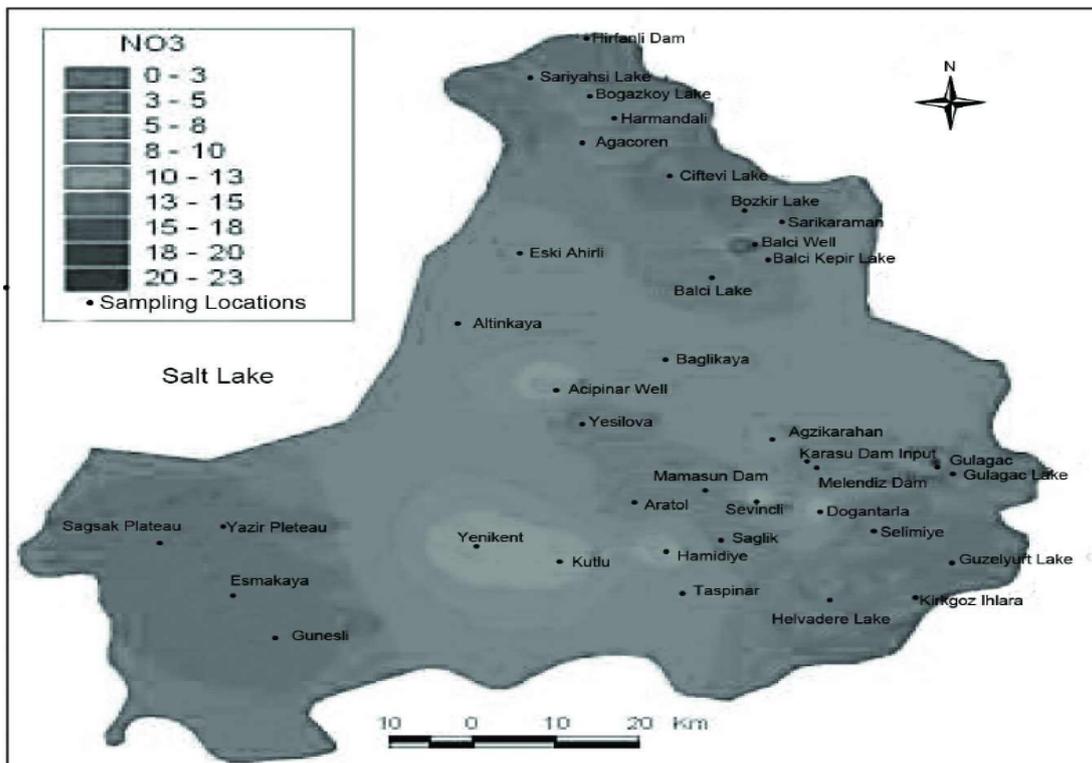


Figure 7. NO_3^- (mg/L) distribution of irrigation period in Aksaray region

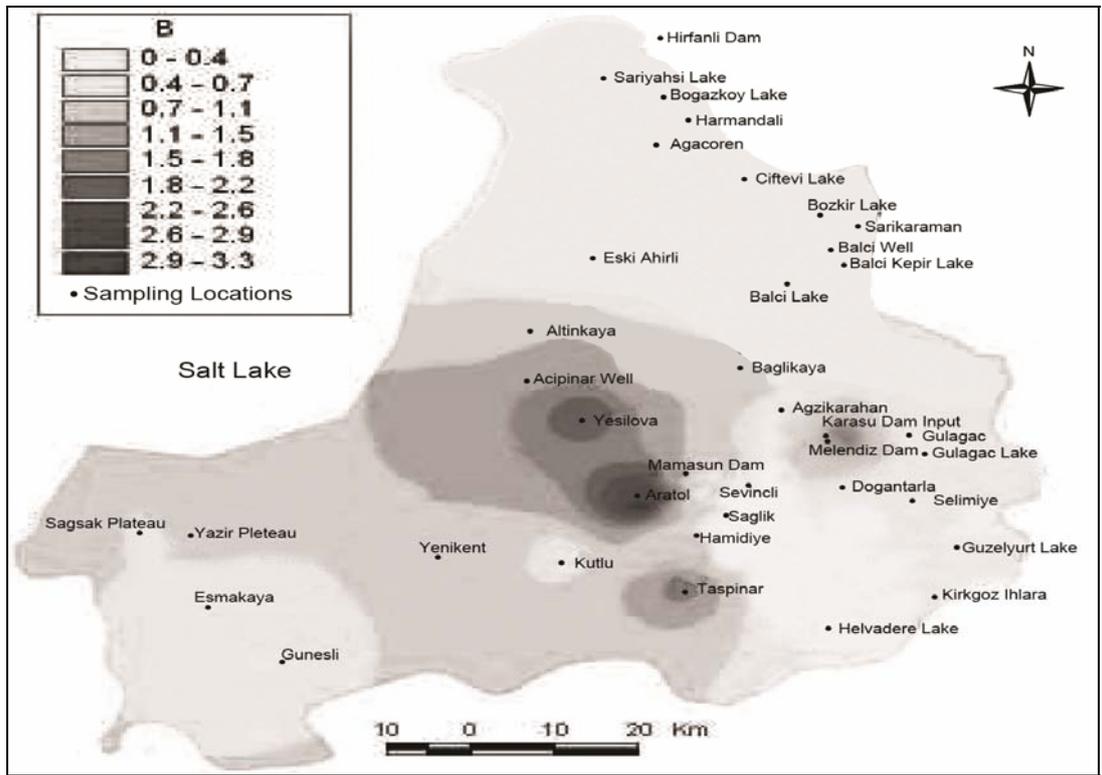


Figure 8. B (mg/L) distribution of irrigation period in Aksaray region

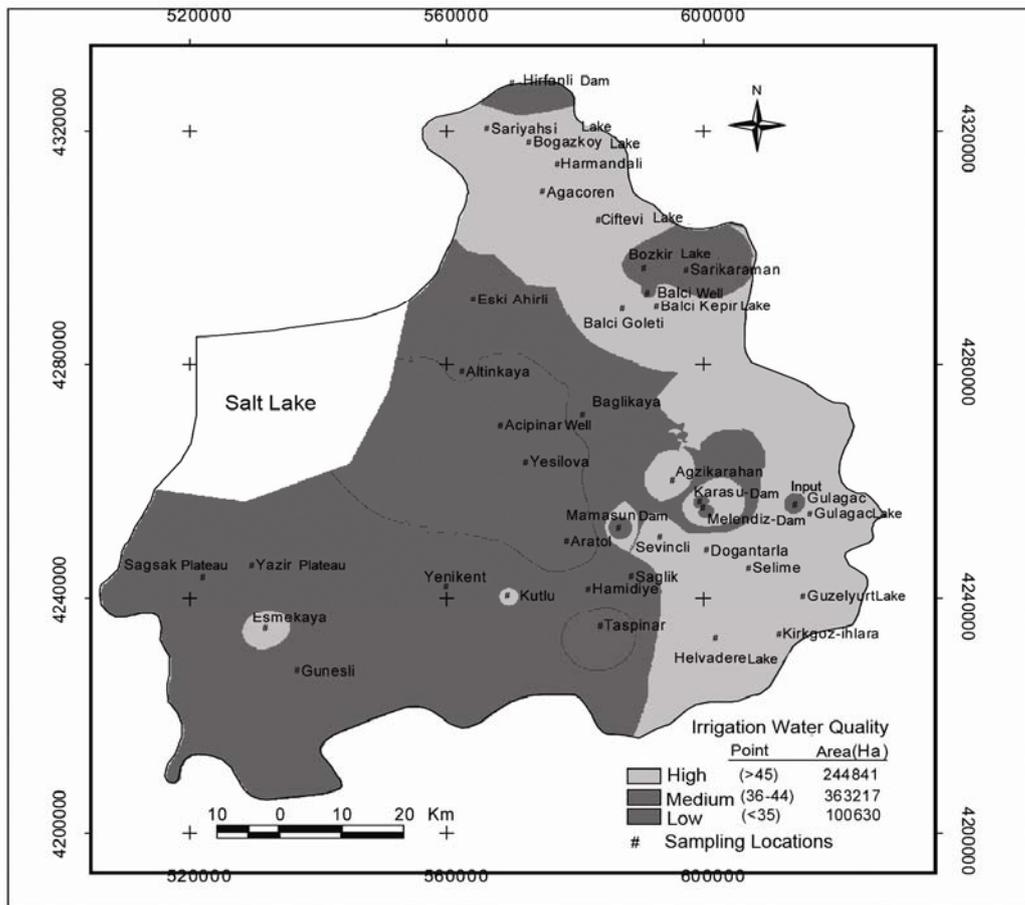


Figure 9. Irrigation water quality index map of irrigation period in Aksaray region

The nitrate concentration values of underground water sources in Acıpinar and Balçı sample points were found as higher than limit values. High nitrate concentration values were caused from domestic wastes and especially transfer of nitrogenous compounds to aquifers by rain and snow water as a result of fertilizing for agricultural activities. It's necessary for these underground water sources not to be used for irrigation, however, if necessary, it's suggested for it to be used without an additional nitrate fertilizing.

Surface and underground water sources were not affected statistically from seasonal variations in terms of Cl^- and SO_4^{2-} concentrations. When the data belonging to irrigation (summer) period were investigated, generally both surface and underground water sources had Ist class irrigation water quality property in terms of Cl^- and SO_4^{2-} . Boron (B) concentration values were not affected from seasonal variations, both surface and underground water sources had Ist class irrigation water quality property.

Residue Sodium Carbonate (RSC) values were affected from seasonal variations. The lowest RSC average value was obtained in summer while the highest RSC average value was obtained in fall and winter. Spring is the transition period. RSC average values of all seasons were found lower than limit values in terms of irrigation water quality and therefore, there was no inconvenience for irrigation.

The precipitation values among irrigation water quality parameters were generally inappropriate (75%) in terms of irrigation. This rate rather increased especially in irrigation periods. For this reason, not only RSC values but also precipitation index values should be taken into consideration in determination of SAR. The average annual rainfall in Aksaray plain is quite below the average rainfall of Turkey. While the total average annual rainfall in Aksaray was 22.6 mm in 2007, it degraded to 19.6 mm in 2008. For this reason, irrigation is an obligatory in order to sustain agricultural activities in Aksaray plain. Since the surface water and groundwater potentials of the region are not enough, just 20% of the area can be irrigated. In 80% of the area, on the other hand, dry agriculture is performed (Republic of Turkey Ministry of Environment and Forest, 2008). In working site where potential of renewable water sources was rather limited, it was suggested to apply especially appropriate drainage system and irrigation method and to use such water sources having this property.

As a result of evaluating irrigation water quality parameters (EC, SAR, RSC, Total dissolved solids-

TDS, B, NO_3 , Total Organic Carbon-TOC) in terms of their seasonal relationships and their relationships between seasons; the correlation between EC, SAR, RSC, TDS and B parameters in fall, spring and summer was at 1% significance level, while in winter the correlation between EC, TDS, SAR and B parameters was at 1% significance level, the correlation between EC, TDS, SAR parameters and RSC parameter was at 5% significance level, the correlation between B parameter and RSC parameter was at 1% significance level and the correlation of EC, SAR, RSC, TDS and B parameters between seasons was at 1% significance level. In the research of Alas and Cil (2002) which was carried out in the sources feeding Mamasın Dam Lake (Melendiz and Karasu streams), it was determined that the sources had generally Ist class water quality. In our study, on the other hand, Melendiz stream had IIIrd and IVth class water property in terms of nitrate, nitrite and total nitrogen while it had IInd class water property in terms of other parameters. This situation aroused the feeling of surface waters of Melendiz stream was exposed to pollution by point and common sources and its water quality decreased gradually (Karadavut et al., 2011). In the research of Kavurmacı et al. (2010) which was carried on the ground waters of Aksaray, it was determined the ground waters generally had medium salinity hazard rate and a low sodium (alkali) hazard rate in terms of irrigation water used according to the USA Salinity Laboratory Irrigation Water Classification Diagram. While the increase of the salinity had showed the presence of enters of the saline water in the south and the south-east shores of The Salt Lake, it have decreased the quality of fresh waters with respect to the drinking and the used water (Kavurmacı et al., 2010).

5. CONCLUSIONS

According to irrigation water quality index map performed according to the averages of irrigation water quality parameters of irrigation period, the surface water sources were found to be appropriate for irrigation with their high and medium irrigation water quality index. It was determined that the underground water sources had low irrigation water quality index value in Taspınar region and along in the range of Tuz lake and generally, on the other hand, they had medium irrigation water quality index value. It's necessary to be careful about type of plants grown, irrigation method and efficient drainage system in order to minimize the loss of efficiency in the productions of these regions. Consequently, it's necessary to take

the precautions given below urgently in order to use present water potential more effectively since the region is in arid and sub arid climatic zone, the renewable water sources are limited and the water potential in the region is used for both using and irrigation.

Unlicensed wells which threaten the surface and underground water sources in the working site should be inspected and the new ones should be opened in a controlled way. For this reason, related institutions and organizations should definitely work coordinately and deterrent punishments should be applied. In order to use irrigation water more effectively, the farmers in the region should be educated, the irrigation method and irrigation management should be determined, usage of pressure irrigation systems should be encouraged, these systems should be designed by experts and appropriate plant pattern should be determined. The water being cheap and uncontrolled causes incorrect and over use, at the same time, it causes washing of artificial fertilizers given to the soil and pollution of surface and underground water sources. For this reason, irrigation water should be priced suitable for its real cost and the wage should be taken depending on the amount of water used in order to get economical optimum values. The rise of the ground water in agricultural areas where there is a drainage problem causes a decrease in efficiency by decreasing the volume of soil and the depth in which plant roots are shaped up. The soil being heavy-texture and salty structure in the region and the level of ground water being high were caused by lack of adequate drainage system. For this reason, good and adequate drainage system should be configured in order to provide no increase in salt accumulation in the soil, to get an opportunity for more appropriate land use and to increase the yield per unit area.

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