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Research Article

Water Quality Assessment for Irrigation Water Use in Lake Hazar Basin, Elazığ, Turkey

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Abstract

The goal of this work was to research the suitability of water sources for agricultural use in the Lake Hazar Basin For this purpose, samples are taken from 61 locations during the wet period and 60 locations during the dry period in 2015 and analyzed pH, electrical conductivity, calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulfate parameters. Based on these analyses sodium percentage (Na%), sodium absorption ratio (SAR), residual sodium carbonate (RSC), magnesium ratio (MR), permeability index (PI) and Kelly's ratio (KR) were calculated. Also, the usability of groundwater in agricultural activities is evaluated according to Wilcox and United States Salinity Laboratory (USSL) Diagrams. The EC, SAR, Na%, RSC, PI, KR and MR values revealed that suitability of waters as irrigation water, except for a few locations close to the lake. Similar results were obtained from classifications made according to USLL and Wilcox diagrams. The thematic maps of water quality parameters displayed that the groundwater quality decreases along the flow path from high elevations to lake level.

Keywords: Lake Hazar Basin, irrigation water quality, thematic maps, SAR, Na%.

Hazar Gölü Havzasında (Elazığ, Türkiye) Sulama Suyu Kullanımı için Su Kalite Değerlendirmesi

Özet

Bu çalışmanın amacı Hazar Gölü Havzasında su kaynaklarının tarımsal kullanıma uygunluğunu araştırmaktır. Bu amaçla, 2015 yılının yağışlı döneminde 61 lokasyondan ve kurak döneminde 60 lokasyondan su numuneleri alınmış ve pH, elektriksel iletkenlik, kalsiyum, magnezyum, sodyum, potasyum, bikarbonat, klorür ve sülfat parametreleri analiz edilmiştir. Bu analizlere dayanarak, yüzde sodyum (%Na), sodyum absorbsiyon oranı (SAR), artık sodyum karbonat (RSC), magnezyum oranı (MR), permeabilite indeksi (PI) ve Kelly Oranı (KR) hesaplanmıştır. Ayrıca, yeraltı suyunun tarımsal faaliyetlerde kullanılabilirliği Wilcox ve ABD Tuzluluk Laboratuvarı (USSL) Diyagramlarına göre değerlendirilmiştir. EC, SAR, %Na, RSC, PI, KR ve MR değerleri, göle yakın birkaç yer dışında, suyun sulama suyu olarak uygun olduğunu ortaya koymuştur. ABD Tuzluluk Diyagramı (USLL) ve Wilcox diyagramlarında yapılan sınıflandırmalarda da benzer sonuçlar elde edilmiştir. Tematik su kalitesi parametre haritaları, yeraltı suyu kalitesinin yüksek kotlardan göl seviyesine olan akış yolu boyunca düştüğünü göstermiştir.

Anahtar kelimeler: Hazar Gölü Havzası, sulama suyu kalitesi, tematik haritalar, SAR, %Na.

Introduction

Groundwater is located beneath the land surface and is accepted to be safe for different uses (Quist et al., 1988). 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 (Ayers and Westcott, 1985). In hydrogeological research, water quality studies are an important part in determining the usability of water in irrigation. The total amount of dissolved salts in the water determines the quality of the water. Poor quality water causes a decrease in infiltration in the soil and has a toxic effect on plants (Ayers and Westcot, 1994). Product yield decreases as a result of deteriorating physical properties of soil (Oladeji et al., 2012). Therefore, it is essential to determine the chemical composition of water in irrigation water management (Khodapanah et al., 2009). For sustainable water management, water quality indexes are simple and understandable parameters, but they are not enough to evaluate the irrigation water quality. Because there may be environmental restrictives. The water quality studies are mostly based on hydrochemical parameters (Jalali, 2007). Irrigation water quality is determined by the amount of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), sulfate (SO_4^{2-}) and nitrate (NO_3^{-}) concentrations in water.

Demer and Hepdeniz (2018) assessed the groundwater quality for irrigation water in Isparta Plain (SW- Turkey) and reported that chemical index parameters have differed in some locations, but all of the waters are groundwater with suitable qualities for agricultural usage. Alavi et al. (2016) investigated water quality for agricultural uses of groundwater in Dez region (Iran) and the study focused on zoning water quality in geographic information system (GIS) environment. Aksever et al. (2016) determined water quality of Başköy springs for irrigation purposes. In the study, they revealed suitable for irrigation purposes of Başköy springs (Burdur, Turkey) and water quality of Çaygözü spring is different the other springs due to the high electrical conductivity and total dissolved solids. Bozdağ and Göçmez (2013) investigated suitability of groundwater quality for agricultural purposes in the Cihanbeyli basin (Turkey). The parameters anion and cation with pH, total dissolved solid, electrical conductivity, total hardness were used to assess the suitability of groundwater. Çeliker (2008) performed classification of groundwaters based on irrigation water quality assessment using Wilcox and United States Salinity Laboratory (USSL) diagrams in Uluova Basin in Elazığ (Turkey) and all groundwaters were divided into two classes marked (C2S1 and C3S1 'appropriate' - 'very good and good') based on the water quality parameters.

The present study focuses on ascertaining the suitability of surface waters and groundwater for irrigation use in the Lake Hazar Basin. The suitability of groundwater for agricultural usage was evaluated by using sodium adsorption ratio (SAR), Na%, residual sodium carbonate (RSC), Kelly's ratio (KR), magnesium ratio (MR) and permeability ındex (PI). Also, the US Salinity Laboratory (USSL) diagram based on SAR and EC, as well as the Wilcox Diagram based on EC and Na% is used to determine water quality for agricultural purpose.

Material and Methods

The research area covers the drainage catchment of the Lake Hazar which is one of the deepest lakes of Turkey. It is located in the west of Eastern Anatolia Region (latitudes 38º24' and 38º34' N, and longitudes 39º8' and 39º35' E). The basin has altitudes ranging from 1238 to 2347 meters above sea level (Fig. 1). The study area has a continental climate characterized by four periods. Because of its high altitude compared to the surrounding basins, summers are mild and winters are colder. Mean annual precipitation is calculated as 416 mm based on records (1929–2016) from Turkish State Meteorological Service in the Elazığ city close to the Lake Hazar Basin. The average annual temperature is 13.1 °C (DMI, 2016). The geological units within the basin have different hydrogeological properties. Alluvium, limestone, sandstone, conglomerate and limestone levels of the geological formations contain groundwater. Especially, a large amount of groundwater was obtained in wells drilled in alluvium. Bean and strawberry are extensively cultivated in a restricted region in the study area.

Water samples are taken from 61 locations during the wet period and 60 locations during the dry period in 2015 and analyzed pH, electrical conductivity (EC), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), sulfate (SO_4^{2-}) and nitrate (NO_3^{-}) parameters. Sampling elevations ranged from 1238 to 1820 m above mean sea level (amsl), and samples included spring, well, surface and lake waters (Fig. 1). pH and EC parameters were determined in the field by WTW Cond 720 measuring instrument. Chemical analyses of the collected water samples were carried out at the laboratories of Elazığ (Turkey) Provincial Special Administration using ion chromatography method.

To evaluate the suitability of the waters in the study area in terms of irrigation water use, Na%, SAR, RSC, PI, MR and KR values were computed using major anion and cation concentrations. For this purpose, the USSL salinity diagram and Wilcox diagram were also prepared.

ArcGIS ver. 10.1 was utilized for preparation of all thematic maps. Thematic maps were made by the Inverse Distance Weighting (IDW) interpolation technique. UTM projection system (Zone 37N and European Datum 1950) selected for georeference of all GIS layers.

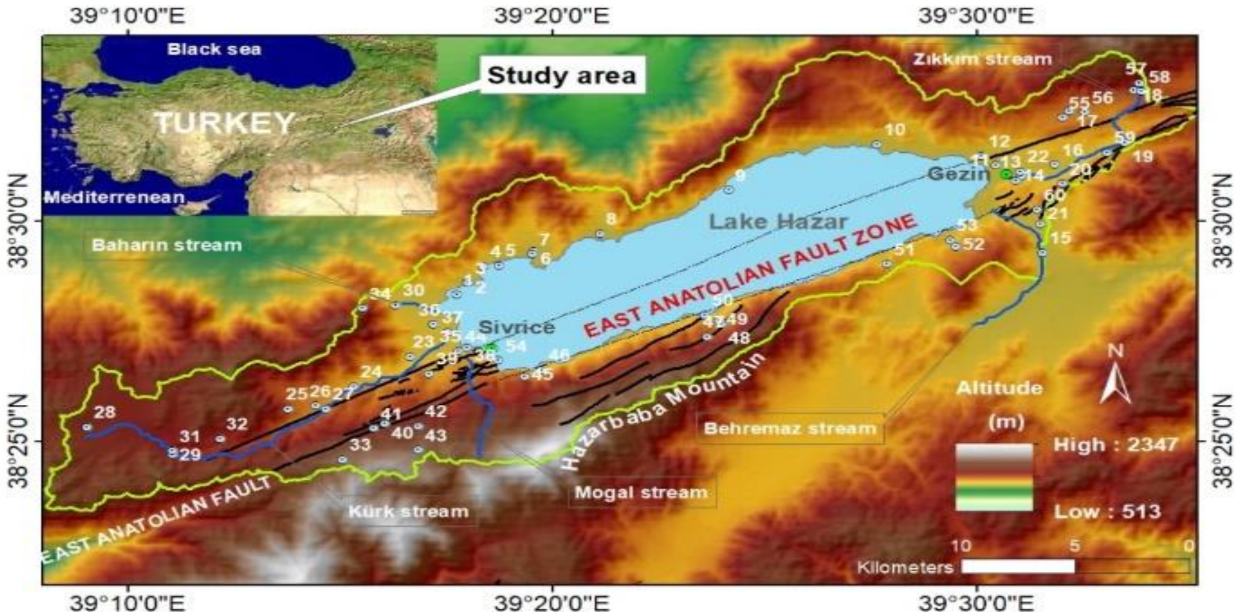

Figure 1. Study area and water sampling locations.

Results and Discussions

The statistical values of the analysis results of the parameters used in irrigation water quality assessment are given in Table 1. In this work, standard water quality parameter indices like EC, SAR, Na%, RSC, PI and MR were evaluated. Besides, based on these parameters, US Salinity Hazard and Wilcox Diagrams were drawn to delineate irrigation quality parameters in the water samples. The results of the calculated index values were presented in Tables 2 and 3. In Figure 2a to Figure 8b, thematic maps depicting the spatial distribution of these irrigation quality parameters were presented for both dry and wet periods.

Table 1. Statistical analysis results of water samples.

Analysis Parameter		Wet period		Dry Period	
		Mean	S.D.	Mean	S.D
EC	µS/cm	430	271.53	437	268.46
Ca^{2+}	meq l^{-1}	46.98	18.69	56.01	54.78
Mg^{2+}	meq l^{-1}	21.95	36.1	25.1	41.32
Na^{+}	meq l^{-1}	11.99	27.02	11.19	17.71
K^{+}	meq l^{-1}	0.62	0.44	0.66	0.5
HCO_3^{-}	meq l^{-1}	276.5	142.43	218.15	140.12

Electrical Conductivity (EC)

EC is an important indicator of salinity hazard to crops. High EC inhibits the absorption of water and nutrients from the soil, as it reduces the osmotic activity of plants (Saleh et al., 1999). EC measurements of water samples range from 130 to 2145 µS/cm (Tab. 2). The results revealed that almost all the parameters are within the usable ranges for irrigation water (Tab. 3). The EC values for wet and dry period are used to create the spatial distribution map for the Lake Hazar Basin (Fig. 2a and Fig. 2b). It is understand that electrical conductivity values of water samples follow similar trend in both periods.

Table 2. Irrigation water quality parameters.

No	Wet period							Dry period						
	EC	Na%	SAR	RSC	MR	KR	PI	EC	Na%	SAR	RSC	MR	KR	PI
K-35	411	4.83	0.15	0.16	35.60	0.05	52.85	419	5.29	0.12	-2.03	39.68	0.06	38.00
SK-36	469	4.25	0.14	2.30	36.94	0.04	57.76	486	3.87	0.13	-1.05	40.25	0.04	42.68
SK-37	499	3.24	0.21	0.43	28.19	0.03	42.22	499	3.94	0.25	-1.15	38.97	0.04	42.26
SK-38	729	7.31	0.13	4.39	56.93	0.08	64.97	707	5.00	0.11	-1.82	37.09	0.05	35.26
SK-39	256	6.20	0.11	0.28	22.00	0.07	61.74	266	6.84	0.12	-0.25	24.46	0.07	59.99
SK-40	282	6.82	0.11	1.54	20.48	0.07	96.49	294	4.79	0.09	0.12	14.07	0.05	62.66
K-41	236	3.55	0.13	-0.02	27.47	0.04	58.71	257	4.49	0.15	-0.47	35.16	0.05	59.99
SK-42	352	7.25	0.09	2.74	28.89	0.08	104.45	310	5.54	0.07	-0.68	21.56	0.06	54.56
K-43	149	2.46	0.22	-1.85	8.05	0.03	38.16	188	4.67	0.31	0.17	15.64	0.05	79.77
SK-44	513	9.60	0.10	2.77	72.71	0.11	86.63	513	5.38	0.08	0.37	38.84	0.06	48.45
SK-45	130	10.14	0.29	1.42	40.82	0.12	145.06	138	9.07	0.30	0.46	34.61	0.10	106.48
SK-46	179.9	10.13	0.12	1.22	45.34	0.12	95.74	281	7.93	0.10	0.12	33.30	0.09	65.86
K-47	167	5.55	0.17	-0.36	25.46	0.06	66.14	190	5.93	0.25	0.32	28.27	0.06	82.68
SK-48	221	8.98	0.21	0.57	35.41	0.10	88.65	311	7.20	0.16	0.35	28.79	0.08	63.65
SK-49	182.9	9.70	0.29	0.15	39.23	0.11	80.28	183	9.55	0.16	0.11	38.35	0.11	78.64
SK-50	247	5.19	1.22	-0.14	23.53	0.05	46.87	203	7.41	0.68	0.25	32.13	0.08	79.48
SK-51	763	33.85	0.25	2.75	60.96	0.51	78.75	603	9.51	0.21	0.39	43.75	0.11	46.97
SK-52	288	7.78	0.24	-1.22	26.66	0.08	46.17	520	6.45	0.24	-0.35	35.89	0.07	45.69
SK-53	513	9.60	0.36	1.47	53.86	0.11	70.39	305	13.18	0.40	0.17	42.15	0.15	69.26
K-54	344	10.99	0.17	-0.17	39.62	0.12	56.52	344	13.30	0.20	0.55	49.37	0.16	68.55
SK-55	452	4.92	0.26	0.30	50.07	0.05	52.22	433	5.44	0.60	0.38	50.58	0.06	53.61
SK-56	408	10.46	0.13	-0.40	35.97	0.12	56.88	207	38.33	0.19	0.69	36.09	0.62	102.05
SK-57	574	1.69	0.54	-3.45	64.35	0.02	26.84	788	1.62	0.55	-0.92	82.21	0.02	31.87
SK-58	2010	4.27	0.20	-10.10	88.20	0.04	18.86	2010	4.21	0.20	-10.49	86.95	0.04	18.60
SK-59	461	16.22	0.18	0.58	49.40	0.19	62.18	520	12.74	0.17	-0.13	37.24	0.15	51.00
SK-60	344	17.25	16.19	2.29	92.05	0.21	144.95	492	4.87	8.16	-0.17	31.40	0.05	46.21
L-61	2075	62.54	0.34	2.48	100.00	1.70	78.61							

K:Spring, SK:Well, L: Lake

Table 2. Irrigation water quality parameters.

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SK-36	469	4.25	0.14	2.30	36.94	0.04	57.76	486	3.87	0.13	-1.05	40.25	0.04	42.68
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SK-38	729	7.31	0.13	4.39	56.93	0.08	64.97	707	5.00	0.11	-1.82	37.09	0.05	35.26
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SK-40	282	6.82	0.11	1.54	20.48	0.07	96.49	294	4.79	0.09	0.12	14.07	0.05	62.66
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SK-45	130	10.14	0.29	1.42	40.82	0.12	145.06	138	9.07	0.30	0.46	34.61	0.10	106.48
SK-46	179.9	10.13	0.12	1.22	45.34	0.12	95.74	281	7.93	0.10	0.12	33.30	0.09	65.86
K-47	167	5.55	0.17	-0.36	25.46	0.06	66.14	190	5.93	0.25	0.32	28.27	0.06	82.68
SK-48	221	8.98	0.21	0.57	35.41	0.10	88.65	311	7.20	0.16	0.35	28.79	0.08	63.65
SK-49	182.9	9.70	0.29	0.15	39.23	0.11	80.28	183	9.55	0.16	0.11	38.35	0.11	78.64
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SK-51	763	33.85	0.25	2.75	60.96	0.51	78.75	603	9.51	0.21	0.39	43.75	0.11	46.97
SK-52	288	7.78	0.24	-1.22	26.66	0.08	46.17	520	6.45	0.24	-0.35	35.89	0.07	45.69
SK-53	513	9.60	0.36	1.47	53.86	0.11	70.39	305	13.18	0.40	0.17	42.15	0.15	69.26
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L-61	2075	62.54	0.34	2.48	100.00	1.70	78.61							

Table 3. Classification types for irrigation water quality.

Irrigation water quality parameter	Range	Classification	Range (Wet period)		%	Range (Dry period)		%
EC (µS/cm) (Wilcox, 1955)	0 - 250	Excellent	130 - 247	(14)	23.0	134 - 238	(11)	18.0
	250 - 750	Good	256 - 729	(43)	70.5	256 - 707	(43)	70.5
	750 - 2250	Permissible	763 - 2145	(4)	6.5	788 - 2145	(7)	11.5
	2251 - 5000	Doubtful	-		-	-		-
	> 5001	Unsuitable	-		-	-		-
SAR (Richards, 1954; Todd, 1959)	< 10	Excellent (S1)	0.03 - 5.92	(60)	98.4	0.01 - 8.16	(61)	100
	10-18.	Good (S2)	16.19	(1)	1.6	-		-
	19-26	Doubtful/Fair poor (S3)	-		-	-		-
	>26	Unsuitable (S4 and S5)	-		-	-		-
Na% (Wilcox, 1955)	< 20	Excellent	1.69 - 18.62	(57)	93.4	1.62 - 13.30	(57)	93.4
	20-40	Good	24.85 - 33.85	(2)	3.3	32.77 - 38.58	(3)	5.0
	40-60	Permissible	--		-	-		-
	60-80	Doubtful	62.24 - 62.54	(2)	3.3	62.95	(1)	1.6
	> 80	Unsuitable	-		-	-		-
RSC (Ragunath,1987)	<1.25	Safe	-10.10 – 1.22	(33)	54.1	-31.10 - 0.69	(60)	98.4
	1.25-2.5	Doubtful	1.42 -2.49	(23)	37.7	2.34	(1)	1.6
	>2.5	Unsuitable	2.74 - 4.39	(5)	8.2	-		-
PI	> 75	Class I	78.61 - 145	(17)	27.9	78.55 - 106.48	(8)	13.2
	25-75	Class II	25.36 - 70.39	(43)	70.5	31.87 - 70.75	(51)	83.6
	< 25	Class III	18.86	(1)	1.6	17.98 - 18.60	(2)	3.2
MR	< 50	Suitable	8.05 - 49.40	(46)	75.4	11.30 - 49.37	(54)	88.7
	> 50	Unsuitable	50.07 - 100.0	(15)	24.6	50.58 - 98.98	(7)	11.3
KR	< 1	Suitable	0.02 - 0.51	(59)	96.8	0.02 - 0.63	(60)	98.2
	> 1	Unsuitable	1.65 - 1.70	(2)	3.2	1.72	(1)	0.8

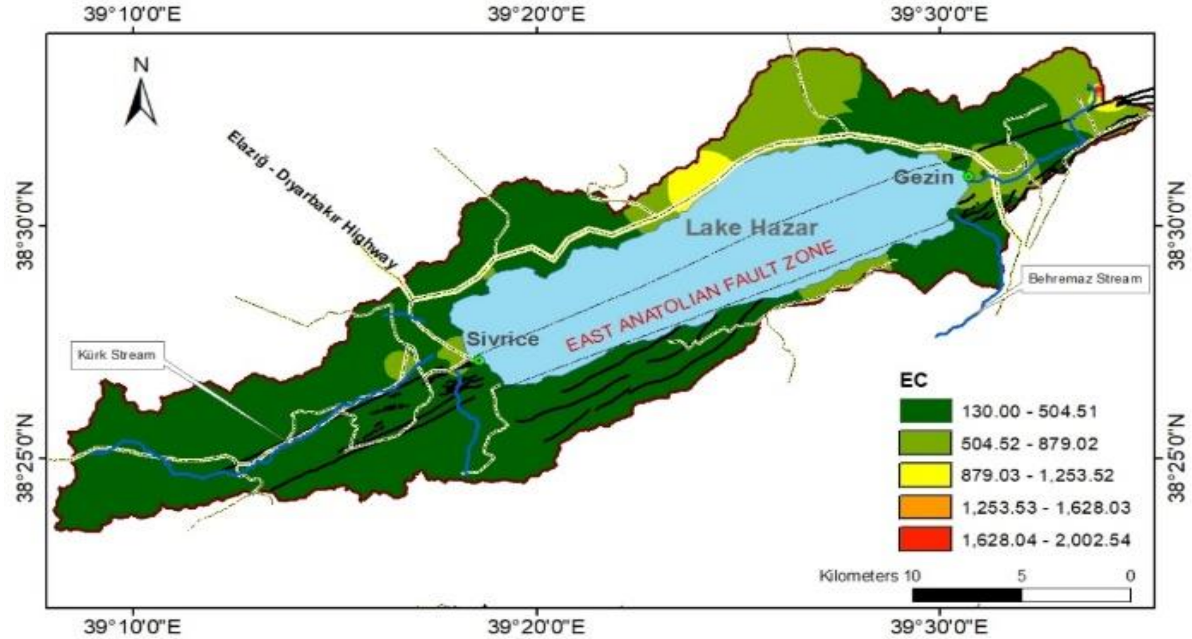

Figure 2a. Distribution map of EC for wet period of Lake Hazar Basin.

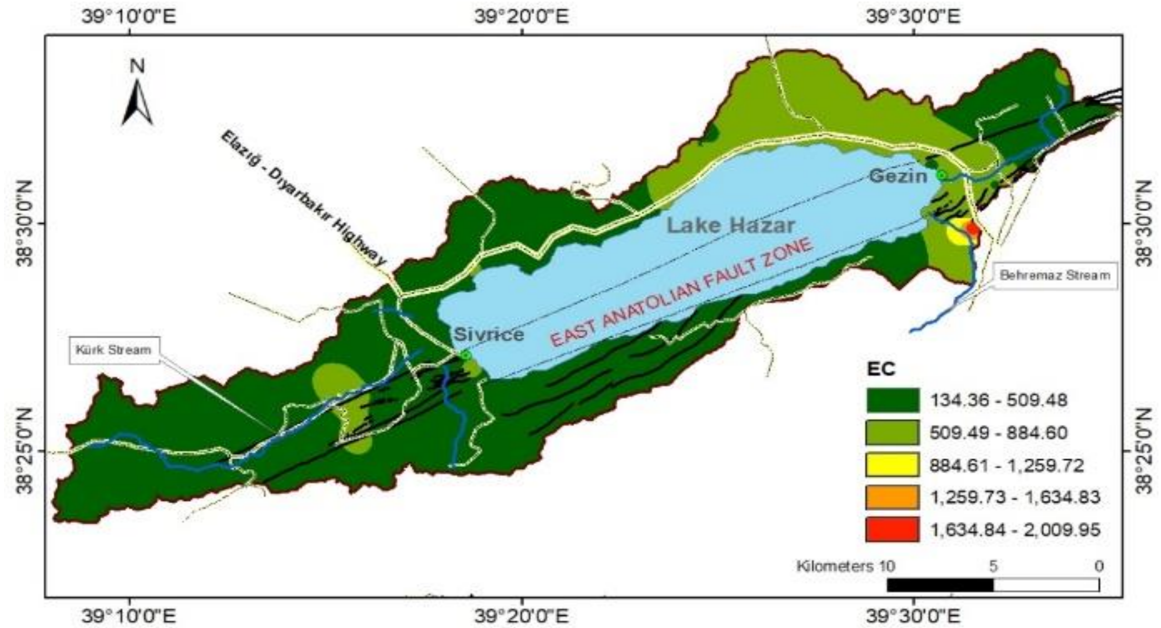

Figure 2b. Distribution map of EC for dry period of Lake Hazar Basin.

Sodium Absorption Ratio (SAR)

SAR is significant criterion for understanding the suitability of water for irrigation because it is a fingerprint of alkali/sodium threat to crops (Richards, 1954; Todd, 1959). SAR values of irrigation water higher than 18 have a negative effect on soil structure and plant development (Richard, 1954). This situation will be seen as permeability problems due to shrinkage and swelling of clayey soils (Saleh et al., 1999). SAR was calculated with respect to relative ratios of major cations available in water, where the amounts of ions are described in meq l^{-1} (see Eq. 1).

$$SAR = Na^+/[(Ca^{2+}+Mg^{2+})/2]^{½} \quad (1)$$

In the wet and dry periods, the SAR values are calculated to be less than 10 (Tab. 2) and are defined as excellent for irrigation, except one sample (SK-60) of the wet period having the SAR value of 16.19 (Tab. 3). Figure 3a and Figure 3b present the spatial distribution maps of SAR values in the basin for both periods and SAR values of water samples also follow similar trends in both periods. During dry period southeast parts of the basin have more SAR values in groundwater compared to wet period.

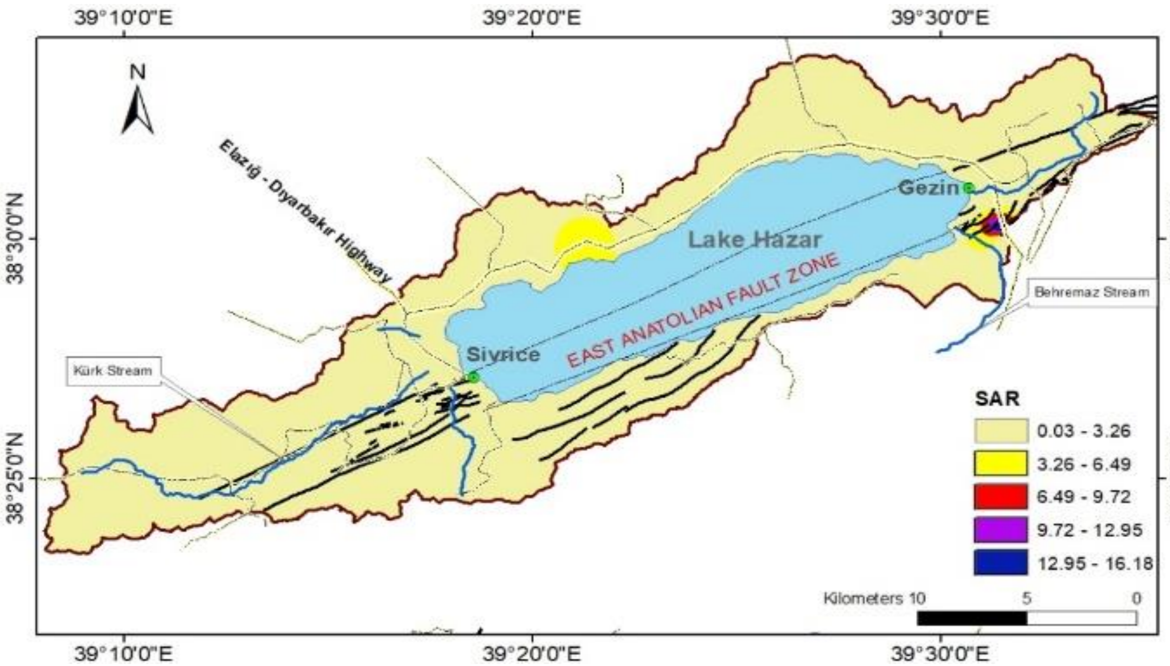

Figure 3a. Distribution map of SAR for wet period of Lake Hazar Basin.

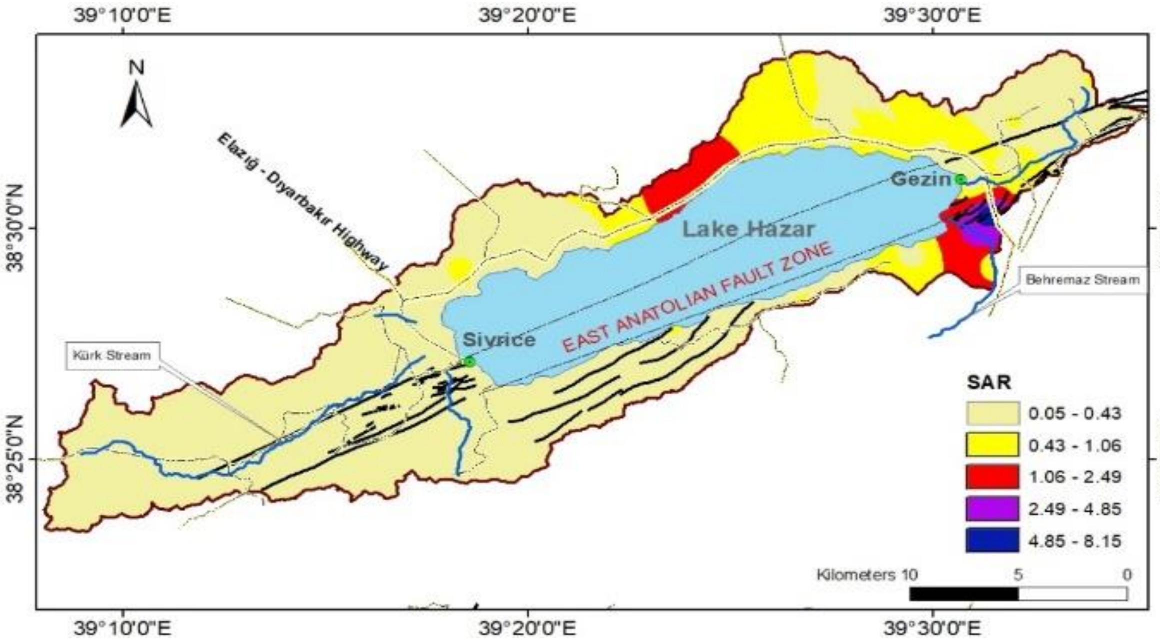

Figure 3b. Distribution map of SAR for dry period of Lake Hazar Basin.

Percent Sodium (Na%)

The sodium cation in water reduces permeability of the soil. This is an undesirable condition in the irrigation water. According to Wilcox (1955), Na % values up to 60 determine the suitability of water for irrigation. Na% values of the waters were calculated by using Equation (2), where the concentrations are described in meq l^{-1} (Wilcox, 1955).

$$Na\ \% = [(Na^{+} + K^{+}) / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})] \times 100 \quad (2)$$

The percent sodium is computed between 1.69 and 62.54 and 1.62 and 62.95 in the wet period and dry period (Tab. 2). It is showed that about 97% of waters fall under excellent to the good class during the wet period while 98.5% of waters are reported in this class during the dry period (Tab. 3). Figure 4a and Figure 4b present the spatial distribution maps of Na% values in the study area for both periods. In the wet period highest Na% values in water is observed in the north parts of the basin whereas in dry period the highest values of Na% values are observed in the northeast parts of the basin.

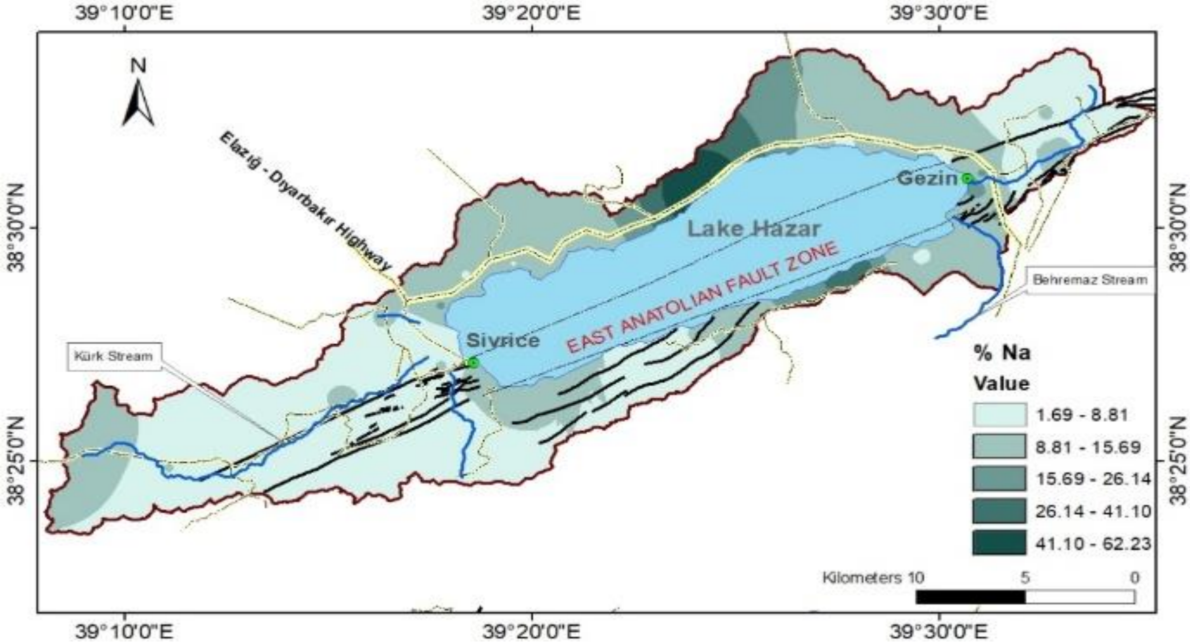

Figure 4b. Distribution map of Na% for dry period of Lake Hazar Basin.

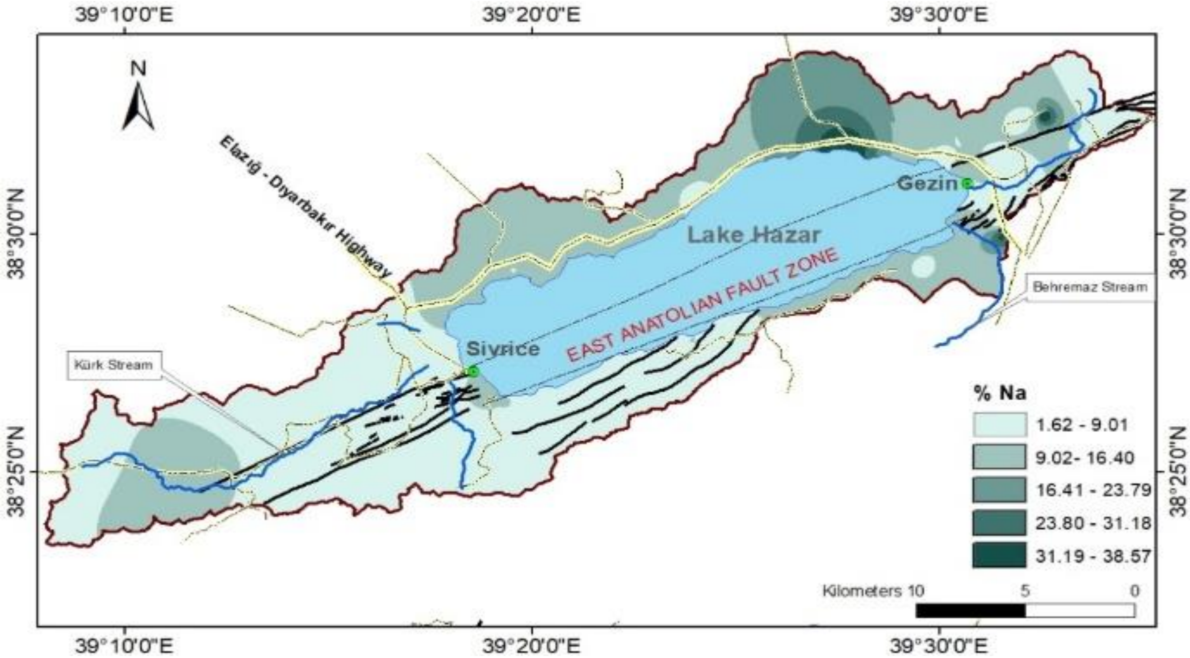

Figure 4b. Distribution map of Na% for dry period of Lake Hazar Basin.

Residual Sodium Carbonate (RSC)

Tiwari and Manzoor (1988) stated that negative RSC values indicate that calcium and magnesium ions do not completely precipitate. High value of RSC in irrigation water is notably harmful for plants growth (Kumar et al., 2009). The (+) RSC value of irrigation water indicates that there is an amount of carbonate and bicarbonate that can combine with sodium to form permanent sodium carbonate and this formation is a risk factor that may cause sodium damage (Sadashivaiah et al., 2008). High RSC value is not desirable in irrigation water because it causes sodification in soil, ie increase in salinity. The (-) RSC value indicates that there is no possibility of sodium damage (Eaton, 1950; Satyanarayanan et al., 2007).

RSC was computed to determine the hazardous effect of carbonate and bicarbonate and is defined by the Eq. (3), where all ions are expressed in meq l^{-1}.

$$RSC = (CO_3^{2-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+}) \quad (3)$$

Based on results, over 33 water samples have RSC values less than 1.25 and are suitable for agricultural irrigation during the wet period (Tab.

2). During the dry period 60 water samples were safe for irrigation. Only one water sample in the wet period and 13 water samples in the dry period were classified as doubtful and five water samples in the wet period as unsuitable (Tab. 3). The spatial distribution maps of RSC in the basin for both periods are shown in Figure 5a and Figure 5b. RSC values varied from -10.09 to 4.39 during wet period and from -31.9 to 0.96 in dry period.

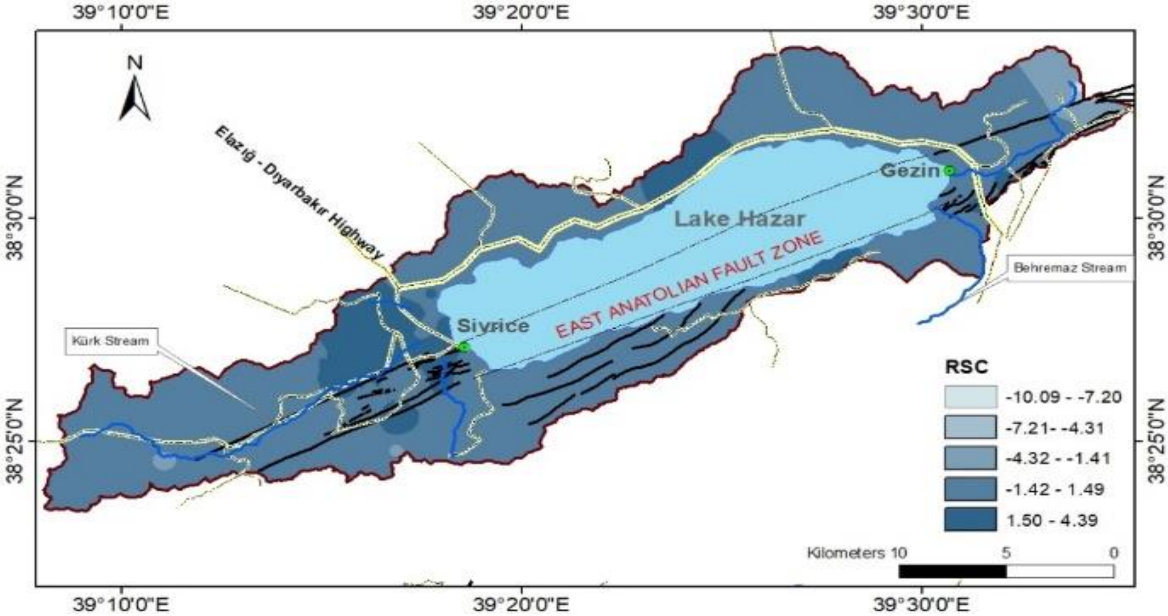

Figure 5a. Distribution map of RSC for wet period of Lake Hazar Basin.

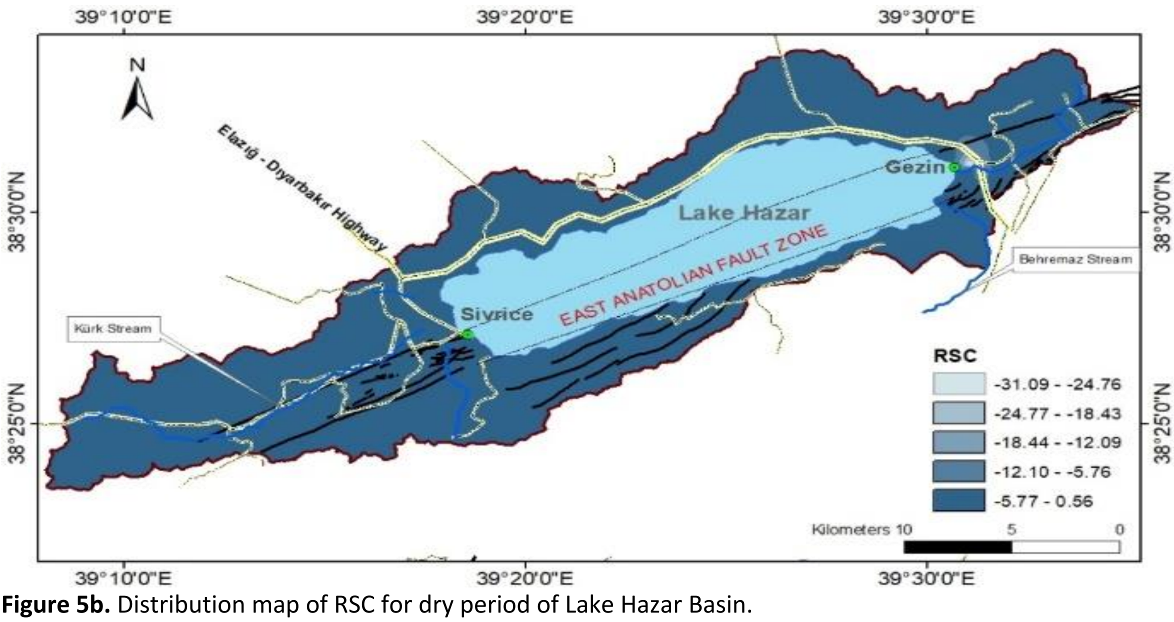

Figure 5b. Distribution map of RSC for dry period of Lake Hazar Basin.

Permeability index (PI)

Long-term use of saline water also has negative effects on soil permeability. Doneen (1964) introduced a new proposal for assessing the suitability of irrigation water based on PI.

The permeability index of Lake Hazar Basin water samples ranged from 18.86 to 145.05 during the wet period, 17.98 to 106.48 during in the dry period (Tab. 2). According to PI, around 98% of waters takes place in the classes I and II of Doneen's classification (Tab. 3). Figure 6a and Figure 6b below are thematic maps where distribution of water PI in the basin has been showed for the wet period and dry period sampling periods respectively.

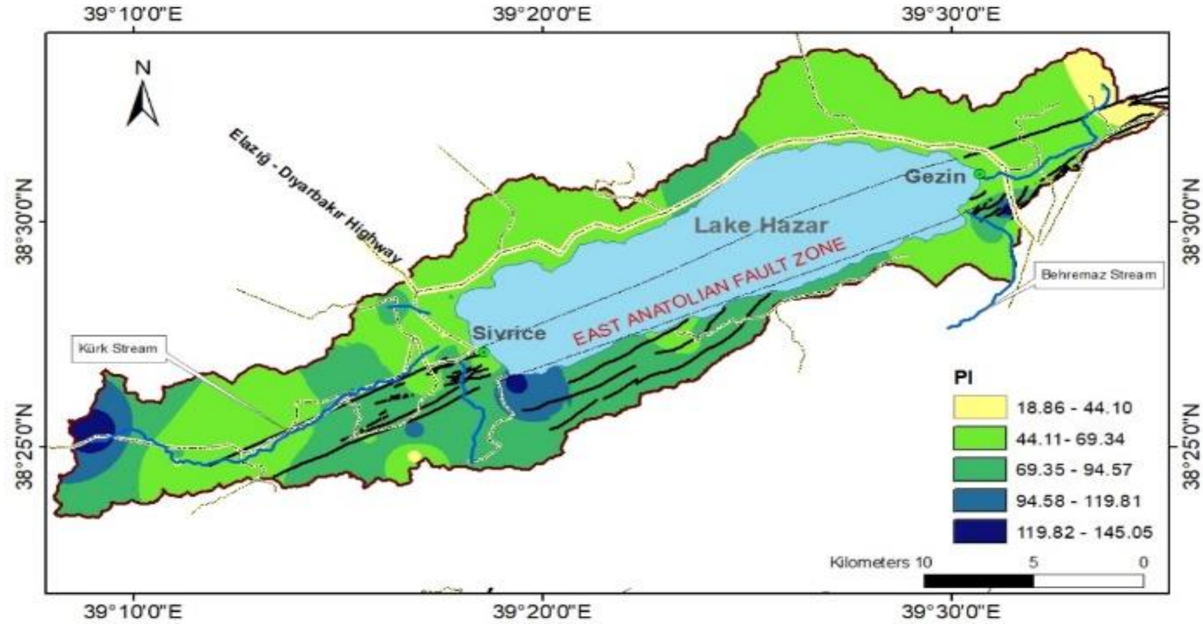

Figure 6a. Distribution map of PI for wet period of Lake Hazar Basin.

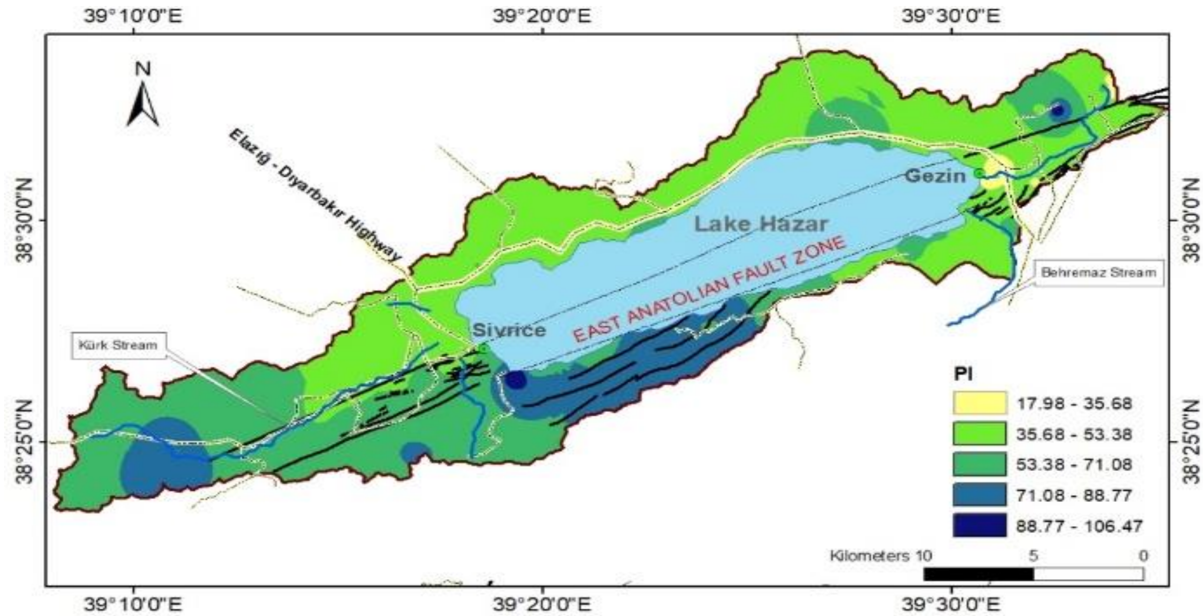

Figure 6b. Distribution map of PI for wet period of Lake Hazar Basin.

Magnesium Ratio (MR)

Raghunath (1987) reported that high magnesium ratio in irrigation water increases soil alkaline level and adversely affects crop yield. It has been suggested that MR values of irrigation water should be below 50% (Szabolcs and Darab, 1964). Magnesium ratio was calculated by using Eq. (4), where all cations are in meq/L.

Magnesium Ratio (MR) = $[Mg^{2+}/(Mg^{2+}+Ca^{2+})]$ x 100 (4)

Figure 7a and Figure 7b present the spatial distribution maps of MR values in the basin for both periods. It is observed that MR values of water samples follow similar trend in both periods. MR values varied from 8.05 to 92.04 during wet period and from 11.30 to 86.94 in dry period. Based on the magnesium ratio, 69% and 81% of the water samples fall under suitable class during wet and dry periods, respectively (Tab. 3).

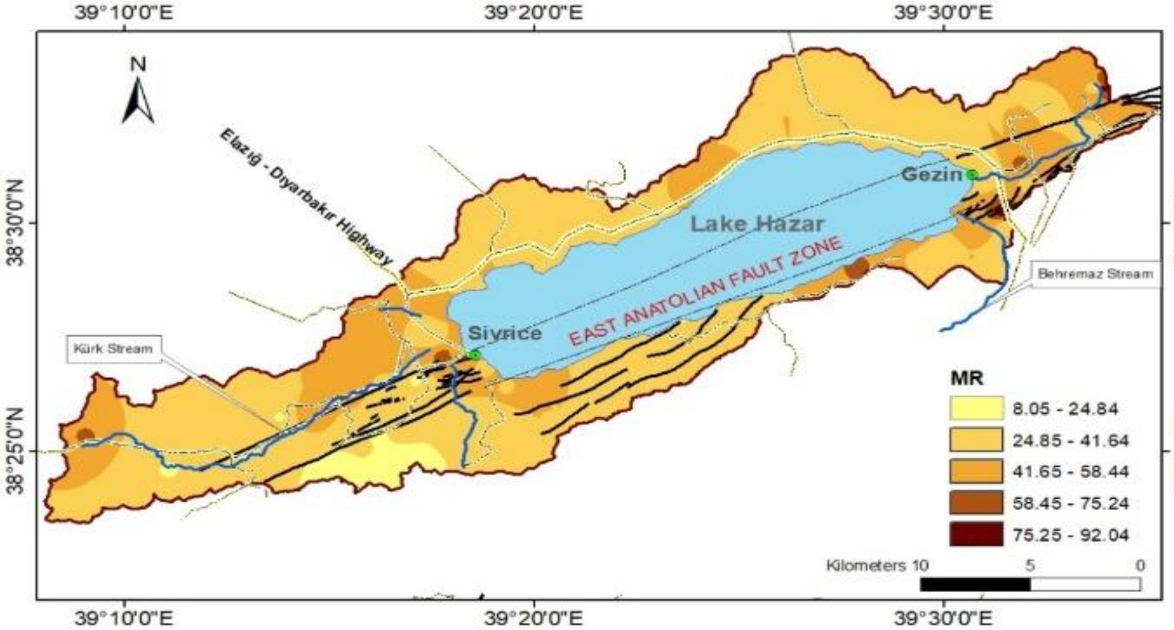

Figure 7a. Distribution map of MR for wet period of Lake Hazar Basin.

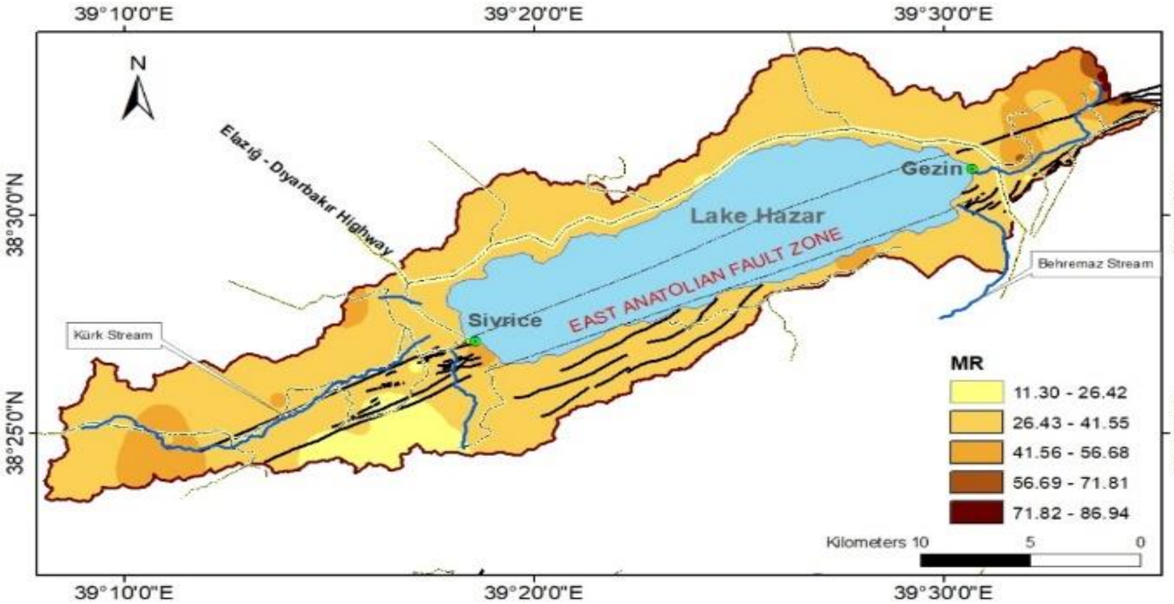

Figure 7b. Distribution map of MR for dry period of Lake Hazar Basin.

Kelly's Ratio (KR)

Kelly (1940) classified irrigation water quality according to the concentrations of Na^+, Mg^{2+} and Ca^{2+} ions. The Kelly's ratio of equal to or less than 1 is express of good quality water for irrigation whereas above 1 is indicate of unsuitability for irrigation water due to alkali hazards (Karanth, 1987). Kelly's ratio was calculated by using Eq. (5), where all ions content are defined in meq l^{-1}.

$$\text{Kelly's Ratio (KR)} = Na^+ /(Ca^{2+} + Mg^{2+}) \quad (5)$$

Kelly's ratio of the water samples ranges between 0.02 and 0.06 (Tab. 2). As per this criterion, the waters are suitable for agriculture purposes except for two water samples in the wet period and one water sample in the dry period (Tab. 3). Figure 8a and Figure 8b represent the spatial distribution of KR in the basin and KR values of water samples show similar trends in both periods.

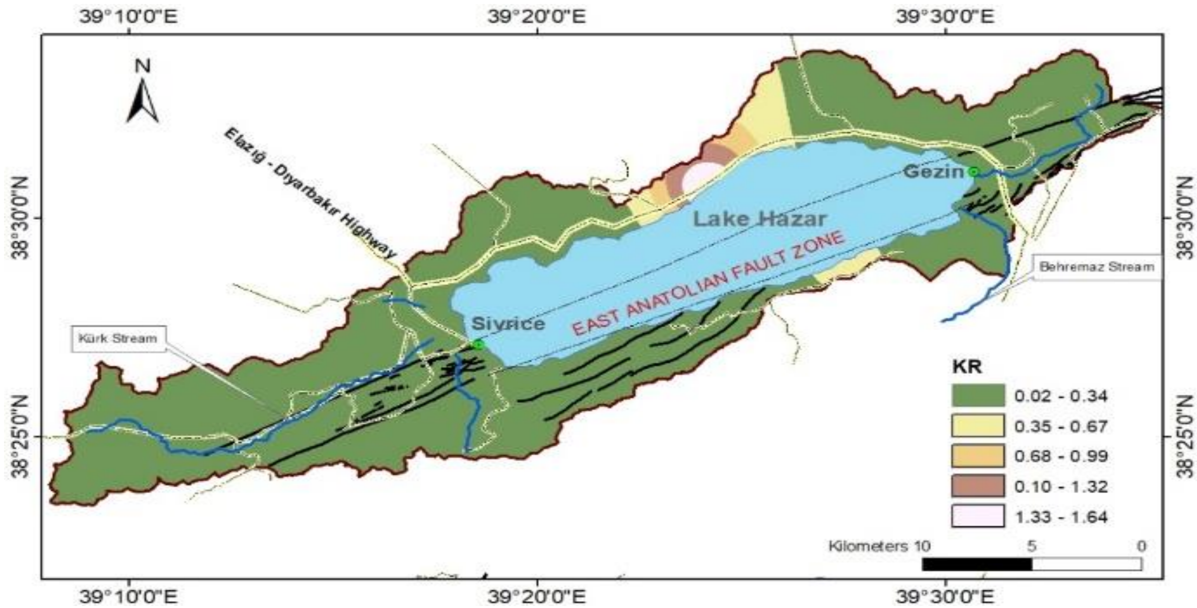

Figure 8a. Distribution map of KR for wet period of Lake Hazar Basin.

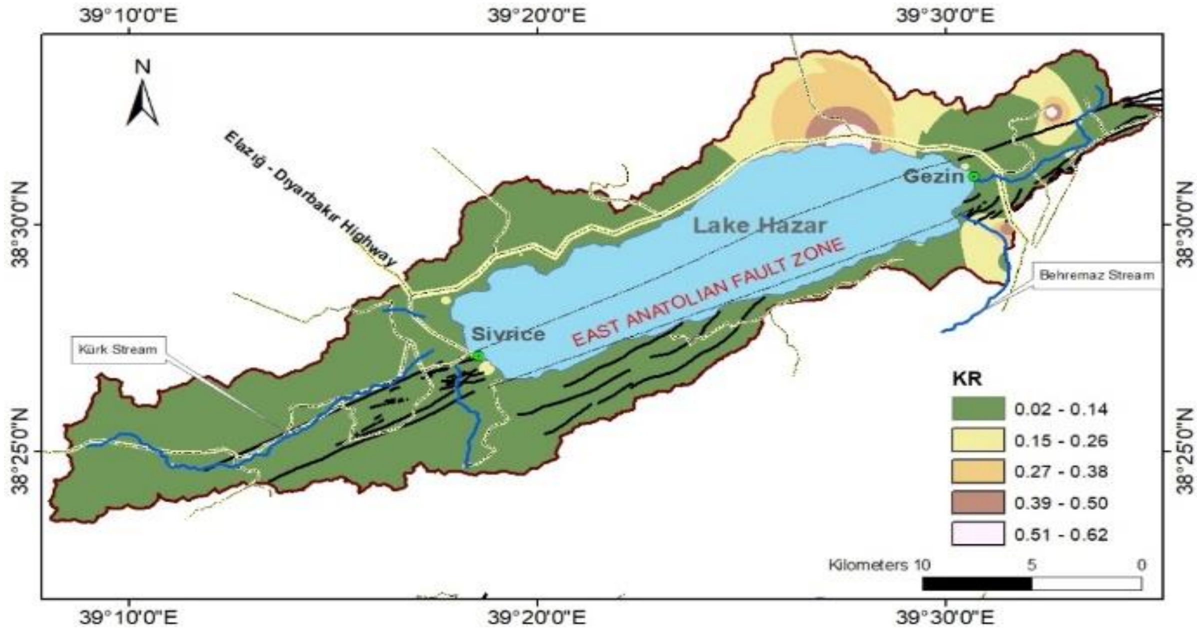

Figure 8b. Distribution map of KR for dry period of Lake Hazar Basin.

In order to understand the suitability water for agricultural use, the US Salinity Hazard Diagram (1954) has been made (Fig. 9). This diagram is based on sodium adsorption ratio (SAR) and the electrical conductivity (EC). The most of waters takes place into C1-S1 (low salinity with low sodium) and C2–S1 (medium salinity with low sodium) classes. In this case, almost all waters are suitable for agricultural activists. Three water samples (4.5%) in the wet period and five water samples (7.5 %) in the dry period are in the class of C3–S1, displaying the high salinity/ low sodium property, which is harmful to products (Khodapanah et al., 2009). The high salinity/medium sodium (C3–S2) property waters should not be used on soils with poor drainage (Ravikumar et al., 2011). About, two water samples in the dry period and one sample in the wet period belong to this category.

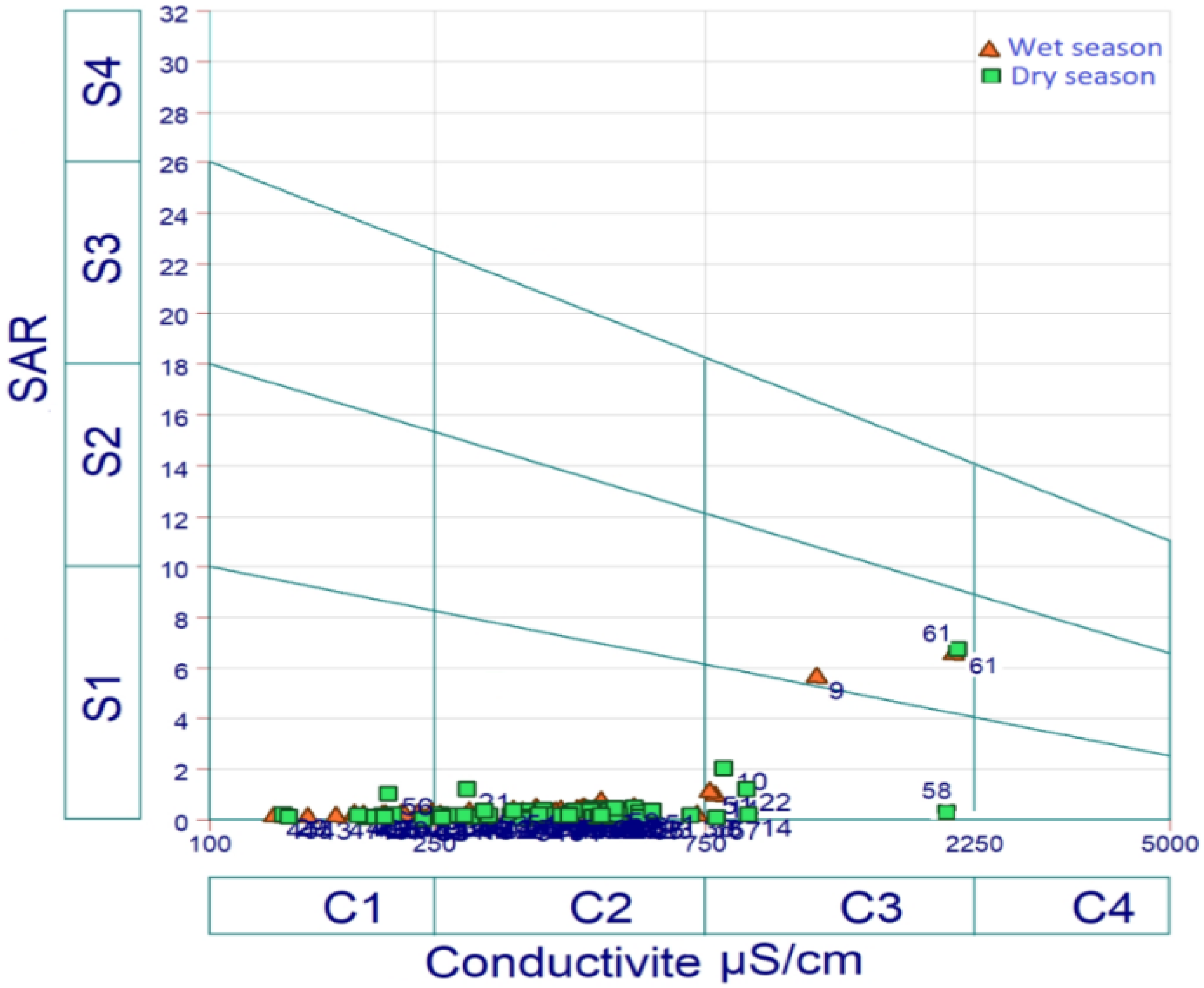

Figure 9. U.S. Salinity Diagram for wet period and dry period.

Na⁺ cation in irrigation water reduces permeability of soil and causes infiltration problems. (Todd 1980). Therefore, another classification to identifying the suitability of irrigation water use is by calculating Na% (Wilcox, 1955). The Na^+ percentage values and the EC measures have been marked on the Wilcox diagram. The Wilcox (1995) diagram indicates that around 58 water samples in the wet period and 57 water samples in the dry period belong to the "very good to good" water quality category (Fig. 10). Two water samples in both periods are defined as doubtful to unsuitable for irrigation water. About for water samples and one water sample in the dry and wet periods are in the class of good to permissible for irrigation water.

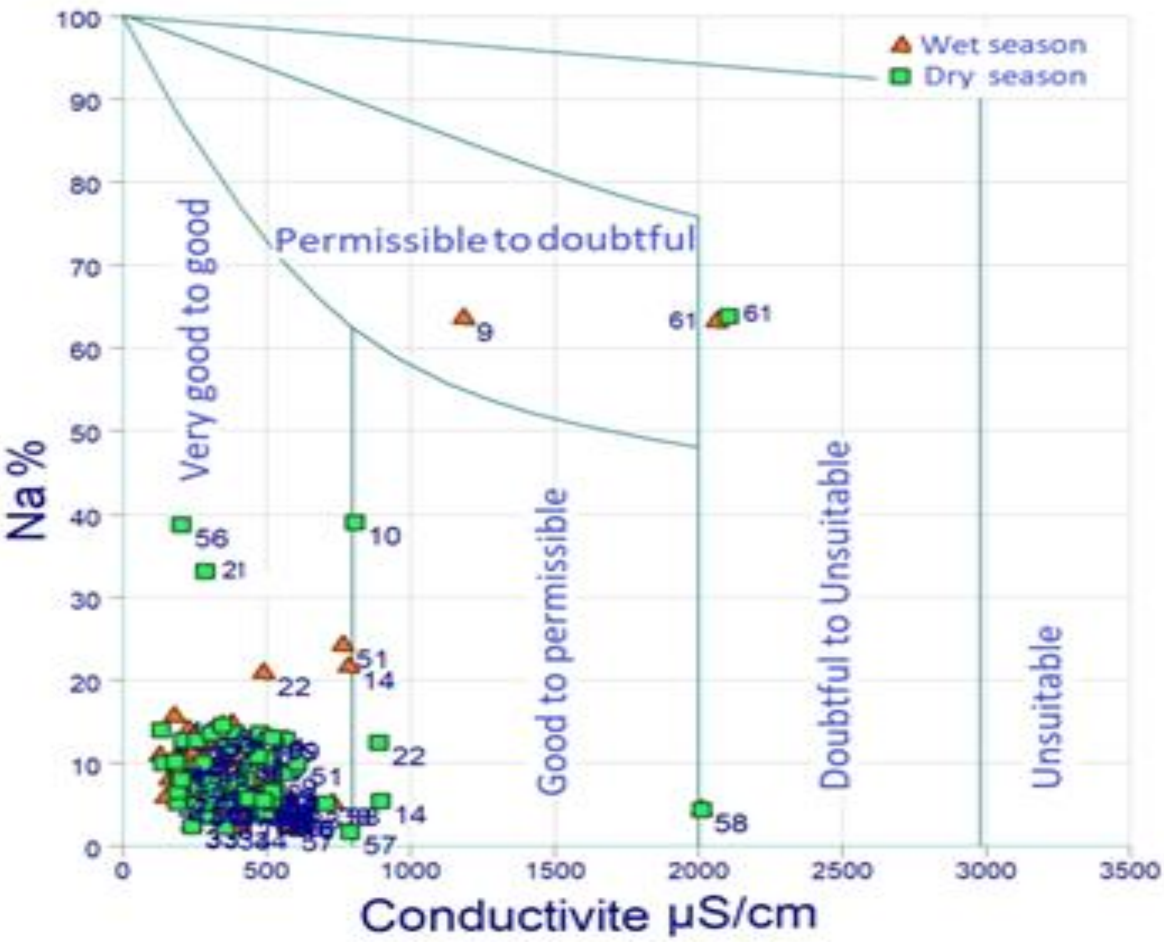

Figure 10. Wilcox Diagram for wet period and dry period.

Aksever (2016) stated that the low of quality in Çaygözü spring is mostly caused by mineralization processes due to rock - water interaction, while Çeliker (2008) stated that the low quality in some groundwater samples was caused by surface irrigation with Keban Dam Lake and Lake Hazar water.

In this study, it was observed that groundwaters in the Lake Hazar Basin were negatively affected by Lake Hazar water with high Na^{+} and EC content. The parameter values for irrigation water show similar trends in both periods. The thematic maps have shown that the groundwater quality decreases gradually along the flow path from the high elevations to the lake level. In addition, it has been observed that water quality decreases in areas where lake.

Conclusions

In this work, the suitability of waters for irrigation were assessed based on SAR, EC, Na%, RSC, PI, MR, KI and salinity hazards. Most of the waters in Lake Hazar Basin fall in the safe range for irrigation purpose with respect to SAR, EC, Na%, RSC, PI, MR and KI values. About 90% of water samples are grouped within C1-S1 (low salinity with low sodium) and C2–S1 (medium salinity with low sodium) categories in both wet and dry periods. Two water samples in the dry period and one sample in the wet period fall in the unsafe range for irrigation purpose from USSL diagram. Also, the Wilcox diagram classifies that most of the water samples as the “very good to good” water quality category in both periods. As a result, the groundwater quality in the Lake Hazar Basin was found to be suitable for irrigation water, except for some sampling sites. The thematic maps of SAR, EC, Na%, RSC, PI, MR and KR show that the groundwater quality decreases gradually from the high elevations to lake level. GIS maps, which can be easily updated in water quality assessment studies, have been understood to be necessary for sustainable water management.

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