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ASSESSMENT OF GROUNDWATER QUALITY AND ITS SUITABILITY FOR AGRICULTURAL PURPOSES IN THE LAKE SEYFE BASIN, TURKEY

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Annotation. The objective was to evaluate of groundwater quality for agricultural uses in the Lake Seyfe Basin, Turkey. For this, 20 different groundwater points were determined in the lake Seyfe Basin and water samples were taken from these points. The following 18 parameters were taken considered for evaluation: pH, electrical conductivity, temperature, sodium, potassium, calcium, magnesium, chloride, nitrite, nitrate, bicarbonate, ammonia, sulphate, dissolved oxygen, total hardness, total dissolved salts, percent of sodium and sodium adsorption ratio. Discriminant analysis was used to determine how the water quality parameters formed groups differ. As a results of the discriminant analysis were compared with guidelines based on various preceding guidelines developed and used in irrigated agriculture. In the study, the values of EC, Na, HCO3, NO3, NO2, TDS parameters were higher than the range of recommended guidelines for irrigation water quality. Further study of these parameters to examine is recommended.

Keywords: groundwater; water quality parameters; factor analysis; discriminant analysis; Seyfe Basin; Turkey.

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INTRODUCTION

Water is a vital element of sustainable agricultural development (Kandiah, 1990). Assessment of water quality is important in terms of improvement and management of water resource. The determination of the physical and chemical properties of the quality of the groundwater is very essential for the use of agricultural such as livestock and irrigated farming, industrial processes and domestic in many countries as well as in our country (Montgomery, 1996; Alsheikh, 2015). The quality of groundwater has lately begun to worry due to the increase in population and thus the increased water demand. Therefore, parameters should be monitered and evaluated for the spatial distribution of groundwater quality and the changes in time that occur, either naturally, or under the influence of anthropogenic factors (Wilkinson & Edworthy, 1981).

The irrigation water quality depends on a number of factors for its successful application and beneficial uses. These factors include soil type, crop selection, climatic conditions, irrigation methods adopted, drainage conditions of the area, fertilizer use, farm management practices followed irrigation supplies. In addition, Hussain and others (2010) reported that the quantity and quality of groundwater depend on the geological formation of underlying strata, the size of aquifer and the site location. Groundwater quality is the sum of natural and anthropogenic influences. The quality of the irrigation water may affect both crop yields and soil physical conditions, even if all these factors are optimal. Therefore; irrigation water quality classification is important for optimizing the use of available water resources. This study is aimed at assessing the ground water and its suitability for agricultural purposes in the Lake Seyfe Basin, Turkey.

MATERIALS AND METHOD

Study area: The study carried out in Lake Seyfe Basin. Lake Seyfe is located in the tectonic depression of north-eastern Kırşehir Province and the centre of the Anatolian Region, Turkey (see Figure 1). It is a Nature Conservation Site and Ramsar Site covering 10.700 ha. At the same time, it has important bird area, flora and fauna area. Kırşehir’s climate is a continental climate. The winters are cold and snowy, and the summers are hot and dry. According to Thorntwait's climate classification, Kırşehir has a semi-arid climate feature. According to Kırşehir State Meteorological Station, the average annual rainfall and temperature meausured in long period (1930-2016) in the region is 378.4 mm and 11.4 °C.

Dry farming constitutes 91.7% of the total agricultural area; 8.3% of the remaining area is irrigated agriculture in the Basin. The major crops are widely grown wheat, sugar beet, barley, lentil, chickpeas, beans, and sunflower. Agricultural activities in Lake Seyfe Basin depend on groundwater as the main sources for irrigation water. Therefore, producers use the groundwater that feeds the lake Seyfe for agriculture purposes.

Methodology: Groundwater samples were collected randomly from 20 well from different areas of Seyfe Lake Basin, Turkey in the months of June and September of 2011-2015 (see Figure 1). June and September are when most irrigation takes place in this area. The majority of the groundwater wells are consisted of Seyfe, Gümüşkümbet, Yazıkınık, Budak, Kızıldağ and Eskidoğanlı villages. Each of the groundwater samples was analyzed using standard procedures recommended by APHA (1995) in the laboratuary of water quality in Kayseri State Hydraulic Works (DSI).

The following 18 parameters studied include potential hydrogen, electrical conductivity, calcium, magnesium, sodium, potassium chloride, sulphate, bicarbonate, total hardness, dissolved oxgen, temperature, nitrate, nitrite, ammonia, total dissolved solids, sodium percent (Na%) and sodium adsorption ratio. These parameters were compared to the using water quality guideline values for agricultural purposes (APHA, 1980; Ayers &Westcot, 1985, 1994; USEPA, 1986; Kandiah, 1990; Miller & Gardiner, 2001; Shahinasi & Kashuta, 2008).

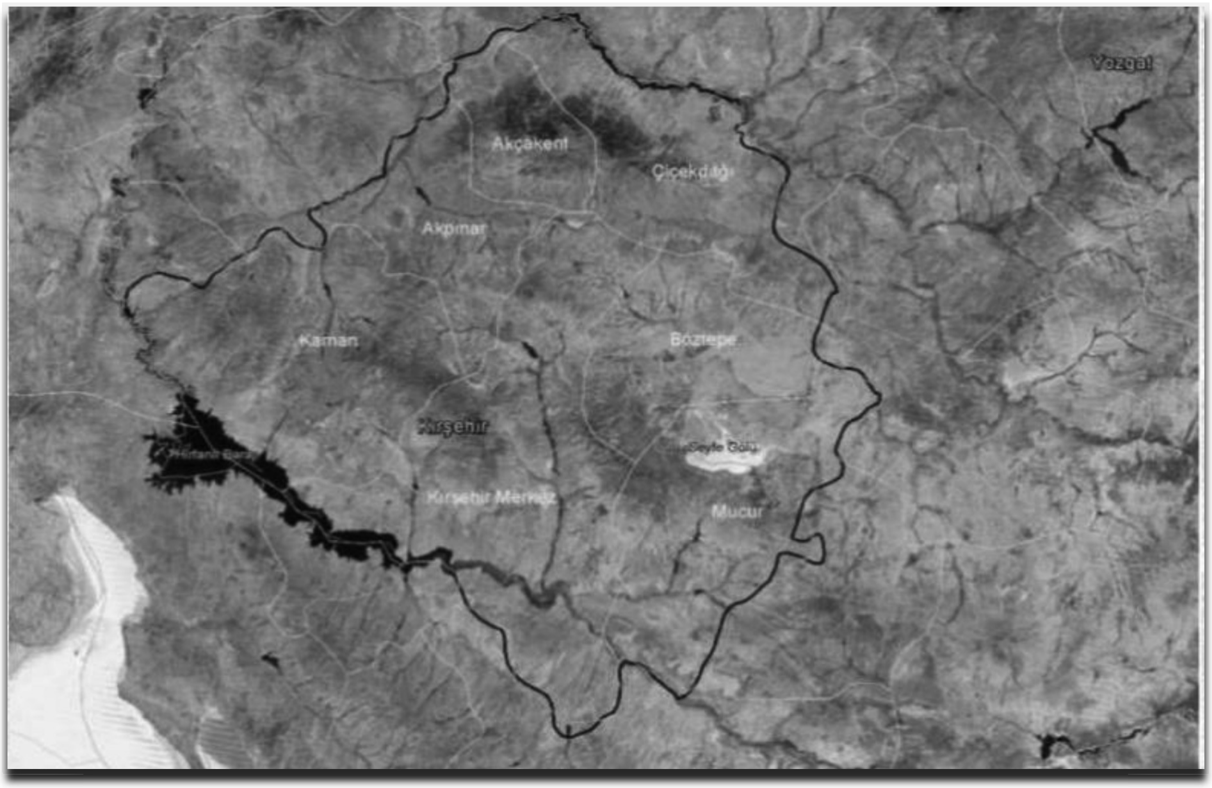

Figure 1. **Location and sampling map of the study area**

Statistical analysis: The obtained variables were used a discriminant analysis and the data were analyzed using the Statistical Package for the Social Sciences (SPSS) 21.0 V Software Package program (Tabachnick & Fidel, 2001; Srivastava, 2007; Özdamar, 2004).

RESULTS AND DISCUSSION

The results of the chemical analysis of groundwater samples obtained from the present study and their statistical parameters included following minimum, maximum, and mean values are given in Table 1 a and Table 1 b. These data are five-year annual average values from 2011 to 2015. The data obtained compared with international standards for irrgation uses (see Table 2). The distribution of parameters groundwater quality also are shown in Figure (2a – 10a).

The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). Irrigation water of wells shows basic charecteristics. The pH values in the study ranged from 7.1 to7.8 with an average of 7.4 (see Table 1 a, Table 1 b, Figure 2 (a)). These values for groundwater samples from wells were within the permissible limit for irrigated agriculture water pH of 6.5–8.5 (see Table 2). Suitability of irrigation water is assessed on the basis of the 'electrical conductivity' (EC). EC values ranged from 37.9 to 2710 µS cm-1, with an average of 594.6 µS cm-1 (see Table 1 a, Table 1 b). Based on salinity hazard classification, EC values of the majority of the well samples are within the permissible range for irrigation purposes, except groundwater sample 16 (see Table 2). Well samples 16 had a very high salinity value and the EC value in water is close to the upper limit range (3000 µS cm-1). Well sample 16 may have harmful effects on sensitive crops and adverse effects on many plants. If precautions are not taken for this well, it will be increasing problem (see Figure 2 (a)).

Calcium values ranged from 3.20 to 380 mg L-1, with an average of 74.4 mg L-1 (see Table 1 a, Table 1 b). The Ca value of sample well of 15 had a high value; whereas others are not represent any risk for use in irrigation (see Figure 3(a), Table 2). Magnessium values ranged from 0.74 to 51.2 mg L-1, with an average of 14.5 mg L-1 (see Table 1). The Mg values of all samples were lower than the acceptable range (Figure 3 (a)). Sodium values ranged from 0.10 to 274.6 mg L-1, with an average of 40.3 mg L-1 (see Table 1 a, Table 1 b). The Na values of well samples 9, 15, 12 and 20 were greater than permissible limit for irrigation uses (see Figure 4 (a)). Other wells are not representing any risk for use in irrigation due to their values lower than permissible limit. Potassium values ranged from 0.01 to 5.64 mg L-1, with an average of 1.5 mg L-1 (see Table 1 a, Table 1 b). The K value of well sample 15 had a high value (see Figure 4 (a)). Other wells are not representing any risk for use in irrigation due to their values lower than permissible limit (see Table 2).

Chloride values ranged from 0.05 to 209.45 mg L-1, with an average of 49.4 mg L-1 (see Table 1 a, Table 1 b). All well of samples were suitable for irrigation purposes due to their values were lower than permissible limit (see Figure 5 (a)). Sulfate values ranged from 0.14 to 111.56 mg L-1, with an average of 21.1 mg L-1 (Table 1). All samples are any risk for use in irrigation (see Figure 5 (a)). Bicarbonate values ranged from 3.84 to 515.45 mg L-1, with an average of 186.7 mg L-1 (see Table 1 a, Table 1 b). The HCO3 values of well samples 15, 10, 11, 9, 14, 12, 18, 20, 16, 19 and 17 had remarkably a very high value and their values were higher than acceptable range for irrigation uses (see Figure 6 (a)). Total hardness values ranged from 17.55 to 362.83 mg L-1 as CaCO3, with an average of 49.4 mg L-1 as CaCO3 (see Table 1 a, Table 1 b). Water hardness is classified according to the following the United States Environmental Protection Agency (USEPA, 1986). Total hardness values of well sample 14 were remarkably very hard water (> 300 mg L-); whereas, others were soft water 75-150 mg L-1, (see Figure 6). Water with hardness less than 150 mg L-1 is considered desirable for plant growth (USEPA, 1986). The hardness of water is generally due to the presence of calcium and magnesium in the water.

Dissolved Oxygen is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. Dissolved oxygen values ranged from 3.38 10.01 mg L-1, with an average of 6.5 mg L-1 (see Table 1 a, Table 1 b). Water quality class well samples 17, 20 and 13 is medium quality, while well samples 16, 12, 9, 19, 11, 14, 10 and 15 is low quality in terms of DO. These results may not cause any irrigational problem as they were within the range of recommended guidelines for irrigation water quality of 0–10 mg/l (see Table 2). Some authors have reported that DO concentrations in water under 5 mg L−1 can cause oxygen deficiency in plant roots, with serious consequences for agricultural production (Gebremariam & Beutel, 2008). In other words, the other wells were high value (see Figure 7(a)). Many studies reported that the actual amount of dissolved oxygen in water is varried depending on water temperature, salinity and atmospheric pressure (Hussain et al., 2010; Alsheikh, 2015). Temperature values ranged from 14 to 17 °C, with an average of 16 °C (see Table 1 a, Table 1 b). The temperature values of the majority of the well samples varied between 16 and 17 °C. These values were suitable range (< 25 °C) for irrigation purposes (see Figure 7 (a)).

Nitrate values ranged from 18.19 to 319.6 mg L-1, with an average of 75.1 mg L-1 (see Table 1 a, Table 1 b). The values of NO3 of all samples had remarkably a very high value (see Figure 8 (a)). These results cause irrigational problem as they were upper the range of recommended guidelines for irrigation water quality of 5–20 mg L-1 (see Table 2). The nitrate concentration in water may increase as a result of contamination with agricultural activities. Algoazany et al. (2005) have reported negative effects on sensitive crops of using irrigation water with nitrogen concentrations above 5 mg L−1. However, most crops do not experience negative effects with nitrogen concentration below 30 mg L−1. Nitrite values ranged from 0.010 to 1.99 mg L-1, with an average of 0.3 mg L-1 (see Table 1 a, Table 1 b). These values of all well samples were higher than upper permissible safe limit for irrigation purposes (see Figure 8 (a)). These problems usually can be overcome with a good fertilization management and irrigation scheduling. Ammonia values ranged from 0.03 to 0.29 mg L-1, with an average of 0.1 mg L-1 (see Table 1). All the NH3 values for water samples from wells were within permissible (see Figure (9)).

Total dissolved solids levels ranged from 247.04 to 7939.7 mg/L, with an average of 969.2 mg/L (see Table 1 a, Table 1 b). The TDS values of well samples 8 and 14 were higher than permissible limit for TDS (see Figure 9 (a)). The type and concentration of salts depends on the geological environment and the source and movement of the water (Wilkinson & Edworthy, 1981; Gebremariam & Beutel, 2008; Khatri & Tyagi, 2014). Glover (1996) stated that the high salt concentrations influence osmotic pressure of the soil solution and affect the ability of plants to absorb water through their roots. Percent sodium values ranged from 5.22 to 57.92% with an average of 19.8% (see Table 1 a, Table 1 b). Percent sodium values of samples groundwater were within permissible range for irigation water quality of 40–60% (see Figure 10 (a)). But, the sodium values of well sample 4 are close to permissible level. The Sodium / Alkali Hazard are typically expressed as the SAR. The Sodium adsorption ratio (SAR) is an irrigation water quality parameter used in the management of sodium-affected soils. SAR values ranged from 0.17 to 4.62 with an average of 1.3 (see Table 1 a, Table 1 b, Figure10 (a)). All SAR values of groundwater samples of the wells in the study were suitable for irrigation purposes, because their values were within the range of recommended guidelines for irrigation water quality of 10–18 (see Table 2).

Table 1a

The results of groundwater water quality analysis

Number of well samples	*pH*	*T*	*EC*	*DO*	*Na*	*K*	*Ca*	*Mg*	*HCO_3*
1	*7.09*	*16.0*	*199.30*	*4.33*	*13.42*	*0.22*	*5.80*	*2.18*	*5.67*
2	*7.28*	*16.0*	*144.30*	*4.03*	*9.02*	*0.13*	*4.55*	*1.80*	*5.42*
3	*7.25*	*16.0*	*158.60*	*4.63*	*9.00*	*0.12*	*5.72*	*2.11*	*5.32*
4	*7.24*	*17.0*	*149.90*	*3.87*	*9.40*	*0.15*	*4.69*	*1.81*	*5.41*
5	*7.43*	*15.5*	*83.80*	*3.96*	*3.09*	*0.05*	*3.79*	*2.05*	*4.28*
6	*7.08*	*16.0*	*196.70*	*4.20*	*13.73*	*0.21*	*6.01*	*2.22*	*6.12*
7	*7.49*	*14.0*	*40.30*	*4.65*	*0.28*	*0.01*	*3.20*	*0.83*	*3.84*
8	*7.82*	*17.0*	*37.90*	*3.38*	*0.10*	*0.01*	*3.26*	*0.74*	*3.96*
9	*7.68*	*16.0*	*543*	*8.53*	*42.1*	*1.13*	*51.76*	*13.08*	*256.81*
10	*7.60*	*16.0*	*365*	*9.35*	*5.37*	*0.59*	*64.84*	*7.46*	*228.14*
11	*7.54*	*16.0*	*383*	*8.88*	*8.78*	*0.75*	*61.60*	*12.17*	*251.32*
12	*7.39*	*17.0*	*651*	*8.20*	*175.03*	*3.83*	*78.74*	*18.28*	*292.80*
13	*7.63*	*15.5*	*1286*	*7.95*	*13.32*	*3.58*	*96.89*	*19.75*	*292.19*
14	*7.79*	*16.0*	*664*	*9.10*	*6.03*	*1.05*	*77.54*	*10.60*	*254.37*
15	*7.29*	*14.0*	*456*	*10.01*	*274.6*	*5.64*	*379.99*	*43.45*	*156.16*
16	*7.35*	*17.0*	*2710*	*8.18*	*16.99*	*0.72*	*99.50*	*17.32*	*364.78*
17	*7.23*	*16.0*	*622*	*7.56*	*20.89*	*3.7*	*210.09*	*29.96*	*515.45*
18	*7.65*	*16.0*	*1320*	*3.56*	*8.72*	*1.5*	*62.96*	*24.86*	*293.41*
19	*7.26*	*16.0*	*493*	*8.64*	*25.99*	*2.73*	*185.46*	*51.18*	*456.28*
20	*7.35*	*17.0*	*1388*	*7.25*	*149.74*	*3.33*	*81.85*	*27.70*	*333.06*
Mean	***7.4***	***16.0***	***594.6***	***6.5***	***40.3***	***1.5***	***74.4***	***14.5***	***186.7***
Min	***7.1***	***14.0***	***37.9***	***3.4***	***0.10***	***0.01***	***3.20***	***0.74***	***3.8***
Max	***7.8***	***17.0***	***2710.0***	***10.0***	***274.6***	***5.6***	***380.0***	***51.2***	***515.5***

Table 1b

The results of groundwater water quality analysis

Number of well samples	*Cl*	*SO_4*	*NO_2*	*NO_3*	*NH_3*	*Total hardness*	*SAR*	*Na%*	*TDS*
1	*11.03*	*3.38*	*0.039*	*41.10*	*0.170*	*17.55*	*1.35*	*33.18*	*358.65*
2	*6.08*	*2.59*	*0.023*	*42.26*	*0.160*	*18.7*	*0.17*	*5.70*	*247.04*
3	*7.41*	*2.78*	*0.036*	*44.66*	*0.150*	*19.93*	*0.27*	*8.53*	*279.43*
4	*6.64*	*2.71*	*0.053*	*42.41*	*0.290*	*18.68*	*4.62*	*57.92*	*251.45*
5	*2.62*	*1.26*	*0.023*	*26.59*	*0.190*	*27.8*	*0.32*	*8.13*	*753.08*
6	*10.54*	*3.23*	*0.036*	*41.21*	*0.170*	*30.53*	*0.17*	*5.22*	*453.9*
7	*0.12*	*0.14*	*0.010*	*21.84*	*0.090*	*25.09*	*3.56*	*34.50*	*382.6*
8	*0.05*	*0.07*	*0.023*	*19.14*	*0.100*	*105.35*	*0.41*	*10.34*	*2355.9*
9	*27.27*	*18.98*	*0.266*	*62.976*	*0.032*	*26.02*	*0.36*	*6.51*	*363.46*
10	*4.22*	*6.66*	*0.266*	*23.086*	*0.032*	*59.84*	*0.24*	*6.77*	*968.09*
11	*4.94*	*7.48*	*0.266*	*37.862*	*0.032*	*23.76*	*0.44*	*7.71*	*391.22*
12	*175.95*	*111.56*	*0.266*	*45.991*	*0.032*	*69.52*	*3.65*	*50.25*	*1126.1*
13	*49.5*	*33.15*	*0.266*	*92.385*	*0.032*	*40.7*	*1.35*	*33.58*	*968.48*
14	*21.05*	*10.73*	*0.353*	*68.401*	*0.032*	*362.83*	*0.17*	*5.80*	*7939.7*
15	*126.65*	*12.30*	*1.992*	*88.593*	*0.032*	*18.29*	*0.27*	*8.68*	*375.93*
16	*21.86*	*14.52*	*0.266*	*36.389*	*0.032*	*19.25*	*0.20*	*6.81*	*252.57*
17	*125.66*	*81.26*	*0.266*	*311.798*	*0.032*	*20.37*	*4.32*	*55.91*	*287.16*
18	*8.64*	*18.52*	*0.266*	*117.750*	*0.072*	*27.17*	*0.31*	*8.04*	*788.72*
19	*167.68*	*67.27*	*0.266*	*319.562*	*0.032*	*32.29*	*0.17*	*5.19*	*488.26*
20	*209.45*	*23.99*	*0.266*	*18.190*	*0.032*	*23.70*	*3.86*	*37.16*	*352.23*
Mean	***49.4***	***21.1***	***0.3***	***75.1***	***0.1***	***49.4***	***1.30***	***19.8***	***969.2***
Min	***0.1***	***0.1***	***0.01***	***18.2***	***0.0***	***17.6***	***0.20***	***5.20***	***247.0***
Max	***209.5***	***111.6***	***2.0***	***319.6***	***0.3***	***362.8***	***4.60***	***57.9***	***7939.7***

Table 2.

Guideliness for interpretation of irrigation water quality

Water quality parameters	***Symbols***	***Units***	***Usual range in irrigation water***
Potential hydrogen	*pH*	*units (no abbreviation)*	*6.0–8.5*
Electrical conductivity	*EC*	*$\mu S\ cm^{-1}$*	*750–3000*
Calcium	*Ca^{+2}*	*$mg\ L^{-1}$*	*0–400*
Magnesium	*Mg^{+2}*	*$mg\ L^{-1}$*	*0–250*
Sodium	*Na^{+}*	*$mg\ L^{-1}$*	*0–40*
Potassium	*K^{+}*	*$mg\ L^{-1}$*	*0–0.052*
Bicarbonate	*HCO_3^-*	*$mg\ L^{-1}$*	*15-120*
Chloride	*Cl^-*	*$mg\ L^{-1}$*	*25–400*
Sulfate	*SO_4^{-2}*	*$mg\ L^{-1}$*	*200–400*
Nitrate	*NO_3^-*	*$mg\ L^{-1}$*	*5–20*
Nitrite	*NO_2^-*	*$mg\ L^{-1}$*	*0.002–0.05*
Ammonia	*NH_3*	*$mg\ L^{-1}$*	*0–5*
Total dissolved solids	*TDS*	*$mg\ L^{-1}$*	*450–2000*
Sodium percent	*Na*	*%*	*40–60*
Sodium absorption ratio	*SAR*	*ions units $mg\ L^{-1}$*	*10–18*
Dissolved oxgen	*DO*	*$mg\ L^{-1}$*	*0–10*
Temperature	*T*	*°C*	*0–25*

Source: Parameters used in the evaluation of agricultural water quality adapted from APHA 1980; FAO, 1985, Ayers & Westcot (1985), Kandiah (1990), Ayers & Westcot (1994), Miller & Gardiner (2001), Shahinasi & Kashuta (2008).

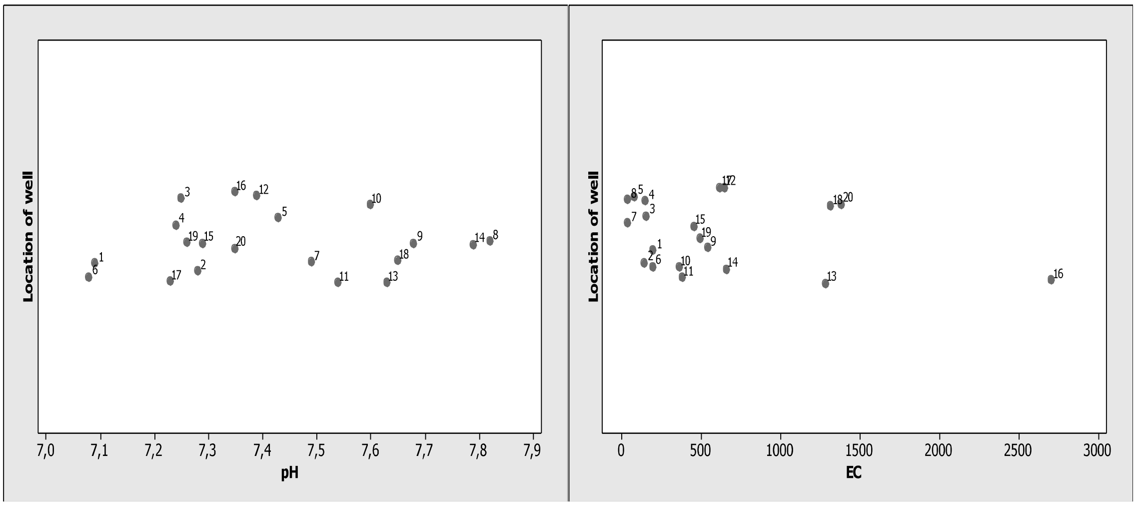

Figure 2 (a). **pH and EC values of well samples**

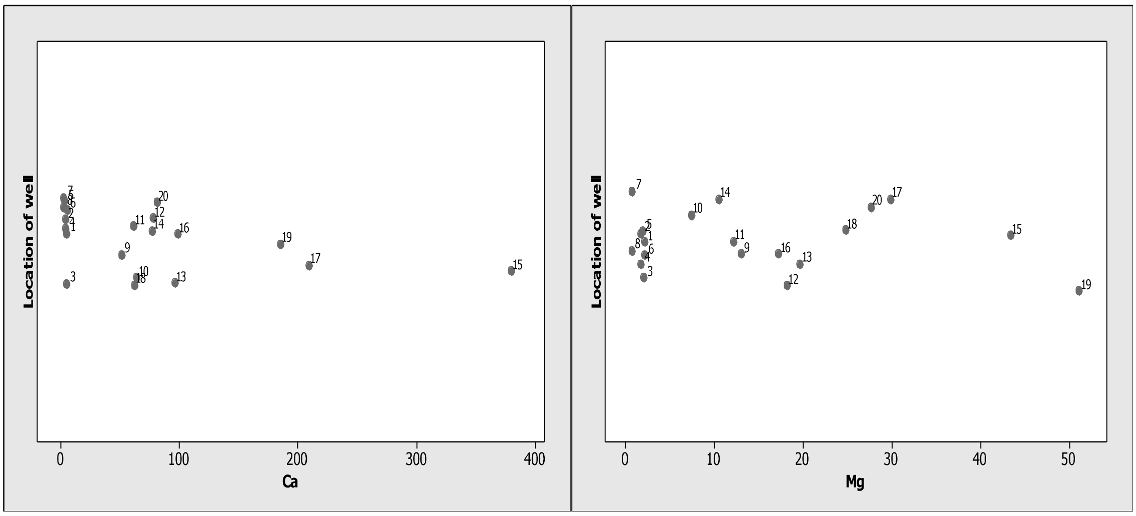

Figure 3 (a). **Ca and Mg values of well samples**

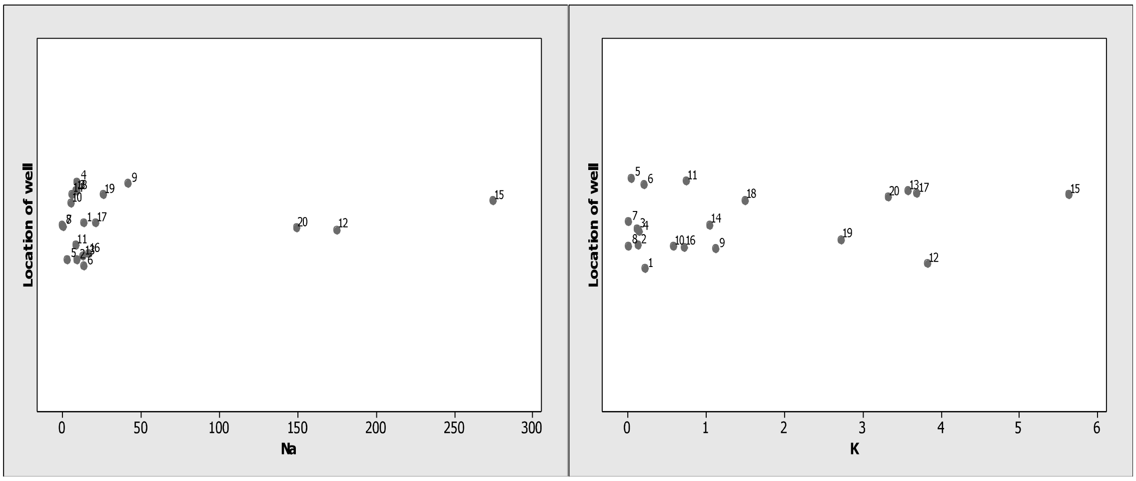

Figure 4 (a). **Na and K values of well samples**

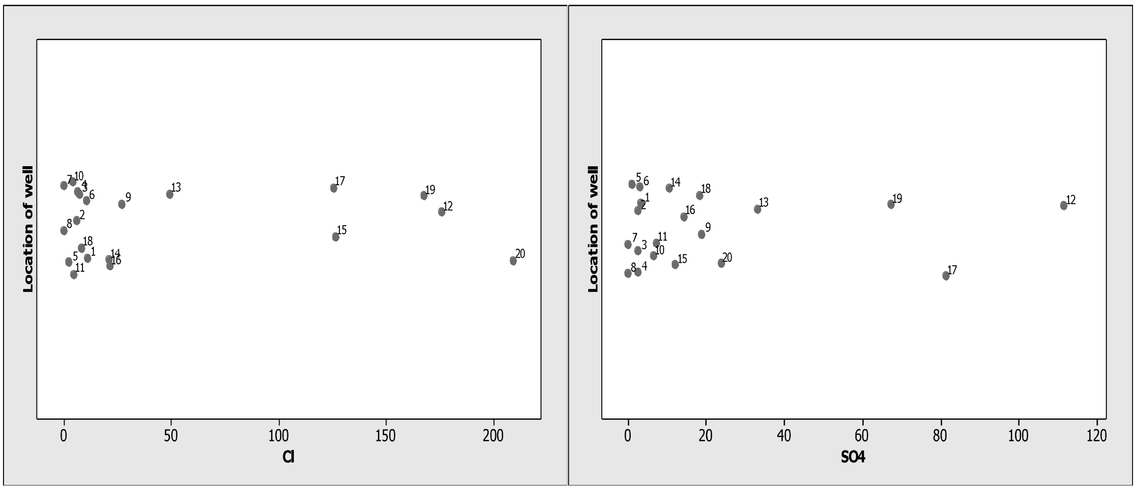

Figure 5 (a). **Cl and SO_4 values of well samples**

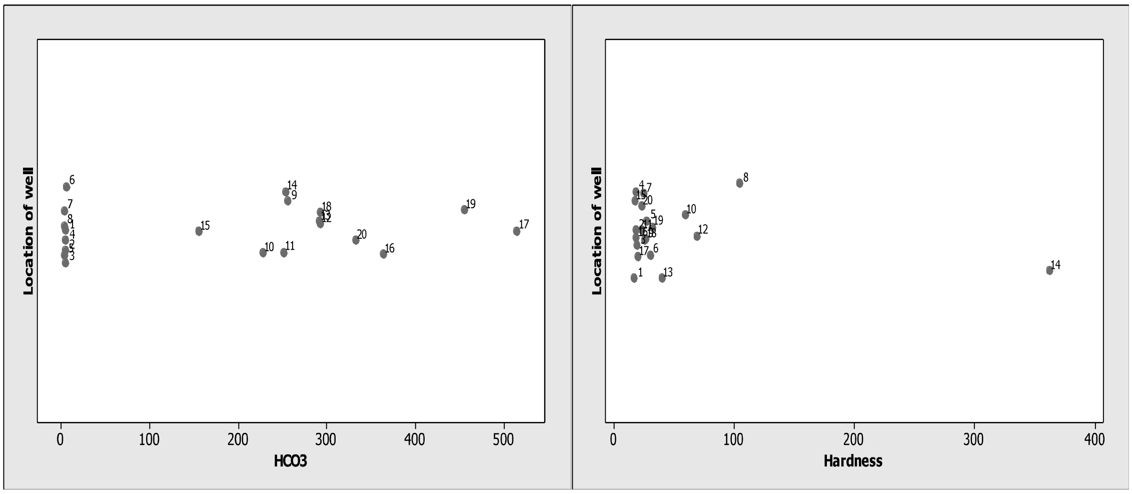

Figure 6 (a). **HCO_3 and Total Hardness values of well samples**

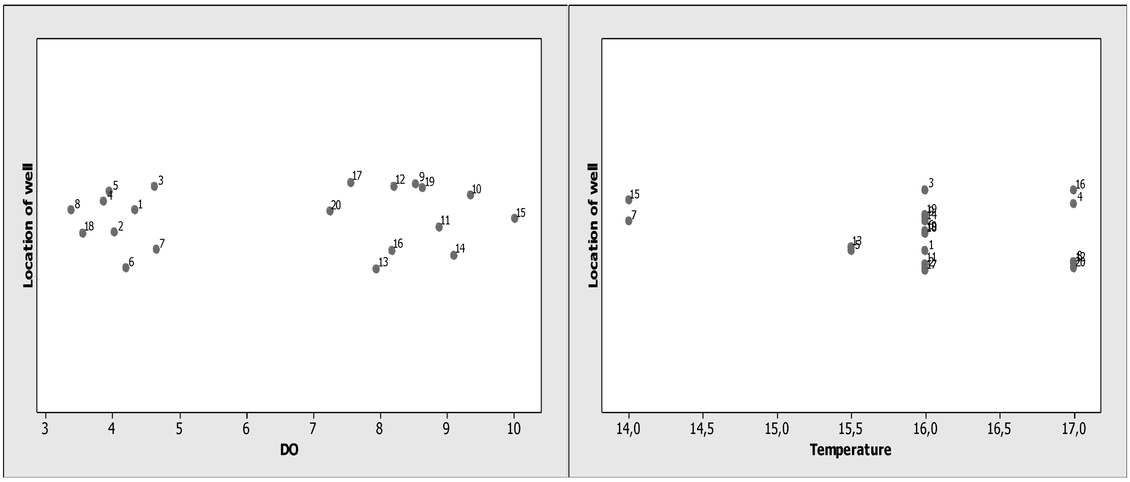

Figure 7(a). **DO and Temperature values of well samples**

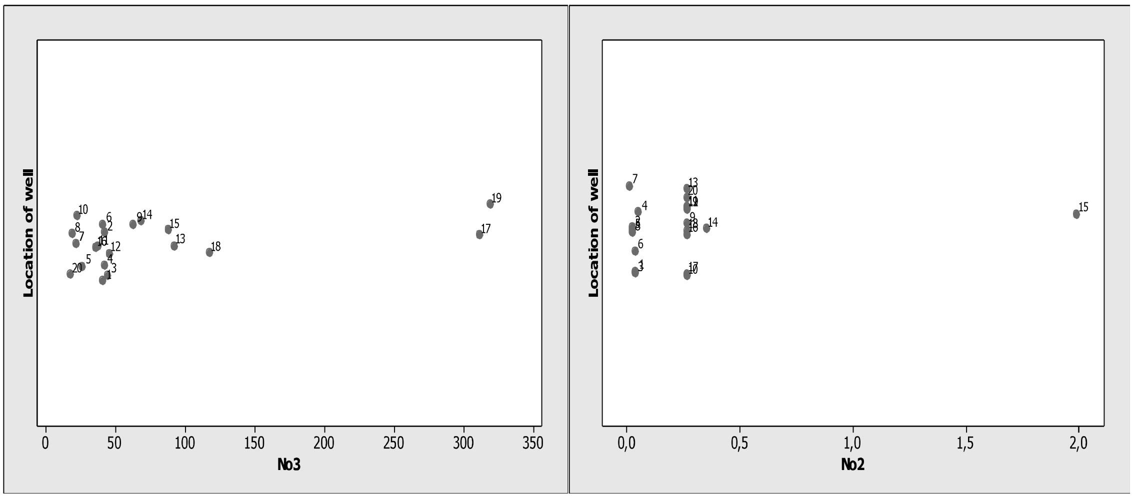

Figure 8 (a). **NO_3 and NO_2 values of well samples**

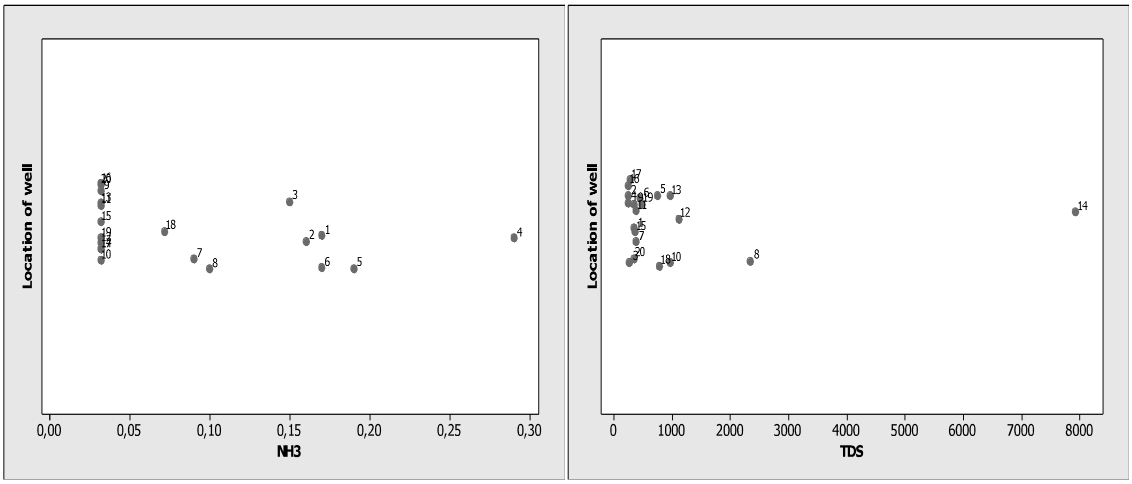

Figure 9 (a). **NH_3 and TDS values of well samples**

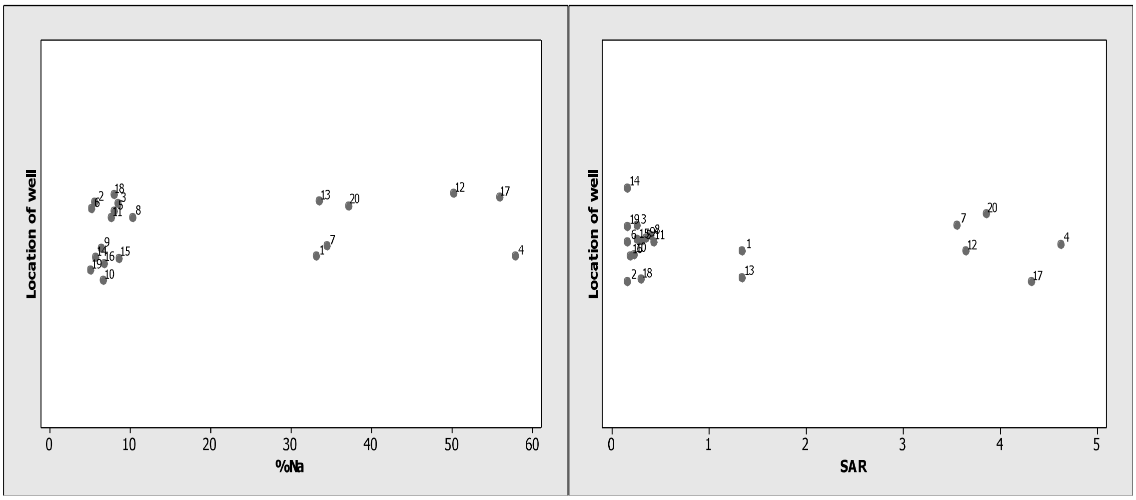

Figure 10 (a). **Na% and SAR values of well samples**

CONLUSIONS

The groundwater qaulity parameters of Lake Seyfe Basin were analyzed and results were compared with guidelines based on various preceding guidelines developed and used in irrigated agriculture. In the study, the main parameter values of EC, Na, HCO3, NO3, NO2, TDS were higher than the range of recommended guidelines for irrigation water quality. The main reasons of these are intensive agricultural factors such as fertilizer, irrigation water, drainage water, and livestock waste, salinity and atmospheric pressure. These problems usually can be overcome with a good fertilization management and irrigation scheduling. In addition, Çelik et al. (2008) reported that the quantity and quality of groundwater in the Seyfe Basin depend on the geological formation causing the various such as lithogenic pollution and heterogeneity of the Kızılırmak Formation, salinity of the upper soil zones, and evaporation of the trench and channel waters open to the atmosphere. Further the parameters mentioned above should be monitored regularly to sustainability of water resources, ecosytem and continuity of life.

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Summary

Assessment of Groundwater Quality and its Suitability for agricultural purposes in the Lake Seyfe Basin, Turkey

The aim of the study is to evaluate of groundwater quality and its suitability for agricultural purposes in the Lake Seyfe Basin, Turkey. For this, 20 different groundwater points were determined in the lake Seyfe Basin and water samples were taken from these points. The following 18 parameters were taken considered for evaluation: pH, electrical conductivity, temperature, sodium, potassium, calcium, magnesium, chloride, nitrite, nitrate, bicarbonate, ammonia, sulphate, dissolved oxygen, total hardness, total dissolved salts, percent of sodium and sodium adsorption ratio. Discriminant analysis was used to determine how the water quality parameters formed groups differ. As a results of the discriminant analysis were compared with guidelines based on various preceding guidelines developed and used in irrigated agriculture. In the study, the values of EC, Na, HCO3, NO3, NO2, TDS parameters were higher than the range of recommended guidelines for irrigation water quality. The main reasons of these are intensive agricultural factors such as fertilizer, irrigation water, drainage water, and livestock waste, salinity, evaporation and atmospheric pressure. Further study of these parameters to examine is recommended.