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Evaluation of Groundwater Suitability for consumption in Yaychi area (Southwest Kirkuk city - North Iraq)

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ABSTRACT

Groundwater suitability for consumption in the Yaychi area is determined by analyzing groundwater samples of 21 wells distributed in the area, for dry period which begin from May to October 2016 and wet period begin from October 2016 to May 2017. Results indicated that the temperature (T °C) have normal values and the water of low alkaline and excessively mineralized, while most of these samples, for both periods, are slightly – brackish water. The mean ion concentrations for two periods indicates that all major and secondary ions are higher than water quality standards for drinking purposes according to World Health Organization (WQI) and Iraqi Standard (IQS) except for K and Cl ions. The water in the study area is classified as very hard. Kurolov formula shows the presence of three predominant salts $MgSO_4$, Na_2SO_4 and $CaSO_4$, and the water origin in the area is meteoric water. The predominated of water types are " earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride" and "Normal earth alkaline water with prevailing sulphate or chloride". After comparing the ionic concentrations with the water quality standards for different purposes, it was found that groundwater in the area is unsuitable for human drinking, but it's suitable for building and livestock and for growing most types of crops, it is also suitable for irrigation purposes depending on the sodium adsorption ratio (SAR), Soluble Sodium Percentage(Na%) and the Residual Sodium Carbonate (RSC), and unfit for irrigation according to Magnesium Adsorption Ratio(MAR) index. The water in the study area is devoid of heavy metal pollution except (Fe), (Pb) which are shown in water of some wells.

Keywords: Groundwater quality. Piper diagram. Yaychi area. Bai-Hassan Formation. SAR.

تقييم ملائمة المياه الجوفية للاستهلاك في منطقة يايجي(جنوب غرب مدينة كركوك– شمال العراق)

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الخلاصة

تم تحديد ملائمة المياه الجوفية للاستهلاك في منطقة يايجي من خلال تحليل عينات المياه من 21 بئرا موزعة في المنطقة للفترة الجافة التي تبدا من مايس الى تشرين الأول 2016 والفترة الرطبة تبدا من تشرين الاول2016 الى مايس 2017. وبينت نتائج تحاليل هذه العينات لخصائصها الفيزيائية والكيميائية إلى أن درجة الحرارة لها قيم طبيعية وذات قلوية منخفضة وكذلك ذات معدنية مفرطة ، بينما اغلب العينات في الفترتين تكون ذات مياه قليلة الملوحة. ومتوسط تراكيز الايونات للفترتين تشير إلى أن جميع الايونات الرئيسية

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والثانوية أعلى من معايير صلاحية المياه للشرب بحسب منظمة الصحة العالمية والمواصفات العراقية باستثناء ايون البوتاسيوم والكلوريد. المياه في منطقة الدراسة عسرة جدا. صيغة كرولوف الهيدروكيميائي تبين وجود ثلاثة أملاح سائدة وهي كبريتات المغنيسيوم و كبريتات الصوديوم وكبريتات الكالسيوم والمياه ذات الأصل الجوي. ونوع المياه السائد في المنطقة هي مياه قلوية مع سيادة الكبريتات والكلوريد ومياه قلوية طبيعية مع سيادة الكبريتات أو الكلوريد. وبعد مقارنة التركيزات الأيونية مع معايير صلاحية المياه للأغراض المختلفة، وجد أن المياه الجوفية في المنطقة غير صالحة لأغراض الشرب البشري ولكنها مناسبة لأغراض البناء والتربية الحيوانية ولزراعة معظم أنواع المحاصيل ، كما أنها مناسبة لأغراض الري اعتمادا على نسبة امتزاز الصوديوم والنسبة المئوية للصوديوم القابل للذوبان وكربونات الصوديوم المتبقي وغير صالحة للري بحسب مؤشر نسبة امتزاز المغنيسيوم. والمياه في منطقة الدراسة خالية من تلوث المعادن الثقيلة ماعدا الحديد والرصاص اللذان ظهرا في مياه بعض الآبار.

Introduction

Groundwater is the most important natural resource in the world. A majority of the world's population depends mainly on groundwater as an important source of water supply for industry, agricultural, and for human consumption. The rapid increase in human population of Iraq along with unprecedented industrialization has placed a heavy demand for mineral, energy, and water resources. Water availability is essential for human survival. Out of the 2.8% of the readily available fresh water supplies, groundwater accounts for 0.6%. However, many aquifers and surface water sources, at various locations all over the world, have been contaminated by inorganic and/or organic chemicals. Assessment of the quality of groundwater depends on the chemical and physical parameters of water, which are controlled by climate factors, soil, topography and human activities and thus determine their use for different purposes [1]. Hydro geochemical processes which control the chemical composition of groundwater are precipitation, dissolution, ion exchange processes and the residence time [2,3]. The assessment of groundwater quality status is important for socioeconomic growth and development [4]. The study area has been a part of many previous studies. Parsons [5], which surveyed the groundwater resources comprehensively based on the hydro geological data of Al-Adhaim basin. As well as, he suggested potential usage of agriculture and human purposes. Al-Naqib [6], accomplished a general geological study of Kirkuk. Al-Naqash et al. [7], made a study was designed to evaluate and develop an operational program for wells which excavated during the period of 2001-2003, by the General Company for Water Well Drilling in the Kirkuk Province. Abdul- Razaq et al., [8], prepared a hydrology study of the upper Adhaim Basin, indicating two hydro geological systems, the first confined (Bai-Hassan formation) and second unconfined (quaternary and recent sediments). Saud and Mohammad [9] and Saud [10], studied the hydrogeology and hydrochemistry of Kirkuk block scale 1:250 000, which included the study area, and the study appears to exist the groundwater within two Formations of Mukdadyia and Bai- Hassan as well as Quaternary deposits.

Study Area

The study area is located in Kirkuk province, Southwest Kirkuk city, north east Baghdad by about 254 km. It is bounded by coordinates, UTM (3910147 N) and (3929372 N) and (425358 E) and (440894 E), Figure-1. It covers an area of about (350) km². Geologically, the study area compose of old Quaternary deposits which characterize by presence of layers of gravel and sand with high permeability and thickness helps that be amenable to investment and it is difficult characterized these deposits than layers of the Bai-Hassan Formation, which located down it through drilling process, and Recent Quaternary deposits has little thickness and composed of silt, clay and sand, and investing the water of this layer by drilling shallow wells [7]. Bai- Hasan Formation,composed of the conglomerates interbedded with sandstone, siltstone and claystone. The prevalence of the conglomerates in the Bai-Hassan Formation had been the main reason for considering it as an independent formation [11]. The Al-Fatha and Injana Formations are the borders of the study area from the north-eastern parts, which are represent Kirkuk structure, which is considered one of the most important structures in the province, where divides Kirkuk region into two main hydro geological basins [9]. The common climate in the area is humid to moist according to [12]. The groundwater flow direction in the area from is northeast towards southwest [10]. The aim of the study is determining the physical, chemical properties and the salts prevailing in the groundwater of the study area and knowledge the validity of this water for different purposes.

Materials and Method

The groundwater samples were collected from twenty-one wells in the study area during October (2016) for a dry period and May (2017) of the wet period. Location and depths of the wells used in this study are shown in Table-1. Temperature, Potential of Hydrogen (pH) and Electrical Conductivity (EC), and were measured by HANA (HI9811-5) instrument directly in the field.While cations which include Calcium and Magnesium and also (TH) were analyzed by the volumetric method [13]; and Sodium, potassium by flame photometer [14]. Anions that include Bicarbonate was analyzed by titration with H_2SO_4 using phenolphthalein + Methanol 60% [15]; and Sulfate were calculated by ultraviolet spectra photometer (U.V) and (NO_3) by the same method. And with respect to Chloride was analyzed by titration with $AgNO_3$ using potassium chromate indicator and heavy elements were estimated by Atomic absorption spectrometer [16]. The results of all analysis were used in the classification of water in the study area, for different consumptions.

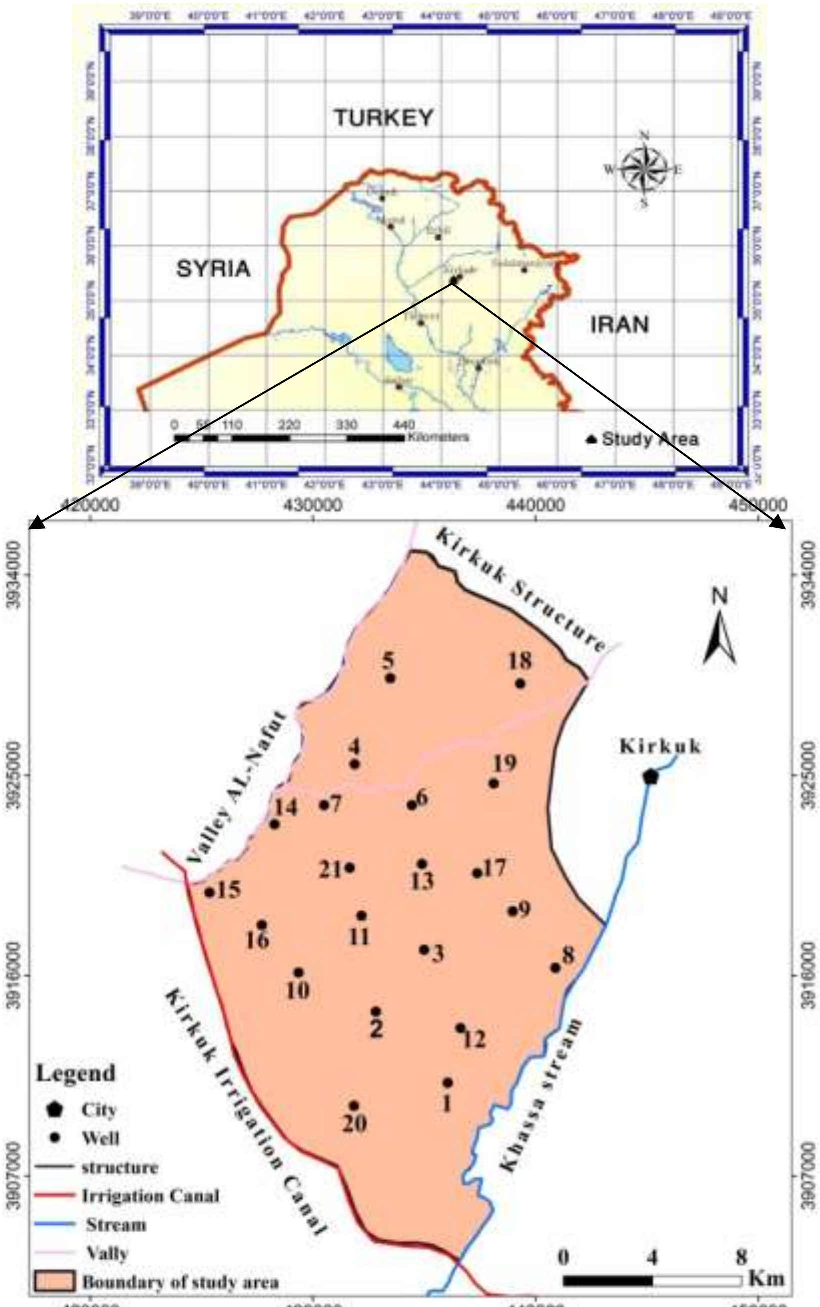

Figure 1- Location map of wells in the study Area.

Results and Discussion

Concentrations of physical-chemical parameters and heavy metals for both periods with standards of WHO [17] and IQS[18], are shown in the Table-4. Results indicated that pH values are ranges between 6.95 – 7.56 in dry period and 7.08 – 7.7 in wet period, which indicated an increasing of alkaline in the groundwater. And, EC values range between 1407 − 7306 μS/cm for a dry period and it ranges between 1600 − 8487 μS/cm for wet period. While the values of TDS are ranging between 816 to 5845 ppm and 928 to 7214 ppm in the dry and wet period respectively, Tables-(2, 3). We observe there are increases in the wet period as a result of the washing the salts of soil by runoff of rain with the remains of fertilizers and pesticides, and also due to sulfur production firm in the area which increase of sulfur ratio in the soil then reacts with the rainwater. All groundwater samples are classified as slightly brackish water except samples (3, 6, 8, 17) in the dry period and (3, 6) in the wet period classified as fresh water according to [19], depending on TDS values, Table-5 and Figures-(2A, 2B).

Table 1- Locations, elevations and depths of wells in the study area

Well No.	X(UTM (East)	Y(UTM) (North)	Elevation (m)	Static water level (m)	Water Head on S.L (m)	Depth (m)
1	436053	3911187	238	6	232	102
2	432825	3914380	242.1	12.11	230	118
3	435000	3917168	253	13.9	239.1	96
4	431876	3925501	275	12	263	120
5	433478	3929372	285	7	278	120
6	434450	3923662	289	6.92	282.1	83
7	430496	3923667	255	9	246	120
8	440894	3916355	280	11	269	78
9	438978	3918887	282	11.5	270.5	108
10	429361	3916140	238.5	10.3	228.2	132
11	432188	3918688	250	12.3	237.7	93
12	436626	3913636	255	12.8	242.2	52
13	434899	3921019	282	6.7	275.3	80
14	428275	3922809	246.5	4.5	242	101
15	425358	3919738	233	3	230	122
16	427711	3918277	237.1	8.12	229	140
17	437375	3920606	289	7	282	72
18	439313	3929129	312	11.4	300.6	80
19	438124	3924633	295	10	285	87
20	431841	3910147	230	4	226	142
21	431650	3920848	266	11.2	254.8	66

Cations

Calcium ion concentration is ranging from 55.68 to 238.6 ppm and from 100 to 561 ppm in dry and wet period, respectively, while magnesium ion concentration varies from 52.07 to 576.35 ppm and from 50.4 to 491.4 ppm in dry and wet period respectively. Sodium ion concentration range between 101.8 - 754.95 ppm in dry period and 66- 810 ppm in the wet period. Potassium ion concentration varies from 1.69 to 5.57 ppm and from 1.67 to 5.02 ppm in dry and wet period respectively, Table-4. From comparing the concentrations of cations with standards of both WHO[17] and IQS[18] results shown that the wells (10,1,4,12,18,20) for the two periods and wells (5,7,13,14,15,16,19) in the wet period shown highly concentrations of calcium, that is because most parts of the study area covered with gypsiferous sediments of Fatha Formation, where water abundance works to wash these soils, and remnant fertilizers that contain calcium. Results of magnesium show that its concentrations are high in most the wells (1,4,5,7,10,12,14,15,16,18,19,20) for both periods due to presence of calcite and some dolomite in Injana formation (Kirkuk structure) and within the components of sandstone, and when water is rich in sulfates at a pH close to the equalization, it will partially dissolve the carbonate, precipitate $CaCO_3$ and releases $MgSO_4$ into water [20]. Also, it could be due to ion exchange of clay minerals that increases Mg^{+2} content. Sodium concentrations have also been higher than standards, above, in the wells (1,5,7,10,12,16,18,20) for two periods and wells (4,14,15) in the dry period, its average concentrations less in the wet period than it in dry period that is attributed to the dilution process by rainfall. While potassium concentrations for both periods are lower than the Na+ concentration because K+ enters the crystal lattice of the Illite mineral, which make difficult to removed in addition to its adsorption on clay minerals that lead to attrition them of the water [21], Tables-(2, 3).

Anions

Sulfate ion concentrations are ranging between 274.5 - 3802 ppm and 360.1 - 4679 ppm in dry and wet period, respectively, and bicarbonate ion is ranged between 150 − 310 ppm in the dry period and between 134 - 327 ppm in the wet period. Chloride ion concentration varies from 84 to 690 ppm and from 46.39 to 588.9 ppm in dry and wet period respectively, Table 4. Comparing these concentrations above with the standards of WHO[17] and IQS[18] shown that the Sulfate ion concentrations are above their level in both periods, because of the melting of gypsum rocks within Fatha Formation and effect remnants of sulfur production factory in addition to the use of some agricultural fertilizers containing sulfur. Results of Bicarbonate ion show that its concentrations are high in most the wells (1,3,7,9,10,11,14,15, 17,19,20) for two periods and in the wells (5,6,13,16) in the wet period, it is clear that the its concentration is greater in the wet period because when pH values in water samples is less than (8.3) all carbonate (CO_3^{-2}) transforms to bicarbonate (HCO_3^-). High concentrations of Chloride ion were noted in wells (1, 16, 18) and (1, 12, 16) in the dry and wet period, respectively generally its average concentration is low in the wet period may attributed to dilution process, Tables-(2, 3).

Nitrate (NO_3^-)

Nitrate concentrations ranged between 13 – 165 ppm in dry period and 33 – 124 ppm in wet period, Table-4. Comparative of Nitrate concentration in the water samples with WHO[17] and IQS[18] found most the samples within safe limits for two periods except wells (1,4,12,16,18,19,20,21) and wells (1,7,10,12,14,16,18,19,20) in the dry and wet period respectively. Its concentrations greater in the wet period due to availability of water, which leads to an increase in the use of nitrogen fertilizers plus washing of the soil during the rainfall Tables-(2, 3).

Total Hardness (T.H)

TH values vary from 353 to 2904 ppm and from 481 to 3432 ppm in dry and wet period respectively, Table-4. Compared these values with values of WHO[17] and IQS[18] found all water samples unsuited for drinking for both periods except samples (3,6,8,11,13,17) in the dry period and sample (3) in wet period which falls within safe limits, Tables 2 and 3. TH values are greater in the wet period due to the melting increase of calcium and magnesium salts and all water samples in the study area seeded as very hard water according to classification of [22] and [23], Table-6.

Table 2- Concentrations of chemical and physical parameters of the dry period by unit (ppm)

W. No.	pH	EC µs/cm	TDS	Cations				Anions			NO_3^-	TH
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SO_4^{-2}	HCO_3^-	Cl^-		
1	6.95	6547	4910	238.63	313.5	754.9	5.13	2520	310	645	72	1890
2	7.27	2348	1409	69.31	111.75	164.9	2.21	704.1	205	121	36	633.6
3	7.37	1407	816	55.68	52.07	101.8	2.29	274.5	212	98	13	353
4	7.19	4275	2779	193.18	279.15	223.4	2	1714	189	121	59	1630
5	7.25	3297	1978	79.54	143.25	300	3.16	976	196	234	45	788
6	7.31	1486	862	60.22	57.75	110.8	1.85	330.3	199	84	25	387
7	6.95	3940	2561	125	211.25	264	3.24	1533	216	150	39	1181
8	7.56	1605	931	59.09	61.7	119.8	1.69	383.2	180	104	20	400.6
9	7.33	1995	1197	79.54	100.33	106.3	2.13	563.1	206	115	34	610.5
10	6.98	4325	3027	170.45	217.95	309	3	1869	270	115	34	1322
11	7.43	1943	1166	73.86	75	151.4	2.37	502.5	220	115	18	492
12	7.5	4320	3024	181.81	270.43	284.2	2.25	1717	150	345	83	1567
13	7.54	1871	1123	79.54	67.66	133.3	1.69	494.8	186	138	36	476
14	7.14	3575	2442	130.68	184.59	250.5	3.04	1330	246	242	31	1085
15	7.08	2893	1881	113.63	159.58	214.4	2.88	877.5	242	230	42	940
16	7.39	5326	3728	142.04	262.5	507.2	5.33	1860	172	690	76	1436
17	7.31	1673	970	62.5	80.1	104.1	2.05	348.7	211	138	40	485
18	7.5	7306	5845	210.22	576.35	475.7	5.57	3802	182	460	165	2904
19	7.35	3038	1823	102.27	160.77	178.4	3.12	902.5	250	184	56	916
20	7.25	5402	3781	159.09	278.5	453.2	4.62	2434	210	153	62	1545
21	7.31	2040	1224	90.9	70.6	151.4	3.12	545.8	173	161	51	517

Table 3- Concentrations of chemical and physical parameters of the wet period by unit (ppm)

W. No.	pH	EC µs/cm	TDS	Cations				Anions			NO_3	TH
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SO_4^{-2}	HCO_3^-	Cl^-		
1	7.08	6095	4571	319.8	242.9	644.5	4.9	2331	327	588.9	64	1801
2	7.63	2535	1521	141	104.8	100	2.31	859	192	87.09	40	782.3
3	7.38	1614	936	110	50.4	69	2.36	428.9	207	46.39	37	481.1
4	7.44	3303	1982	256.5	144.2	90	2.44	1159	183	100.3	41	1233
5	7.5	4188	2722	193	128.9	400	3	1476	203	255.3	49	1012
6	7.38	1600	928	102	60.2	70	1.81	360.1	204	108.3	39	501.7
7	7.4	4493	3145	278	202.6	310	3.03	1928	220	128.8	51	1528
8	7.7	1768	1061	128.2	62.8	74	1.67	484.7	188	98.04	35	578

9	7.6	2036	1222	100	97.1	66	1.72	630	207	92.34	44	648
10	7.17	4579	3205	278	192.3	380	2.85	1773	270	232.5	54	1486
11	7.4	1895	1137	110	64.8	103	2.31	501.6	212	117.4	34	540.5
12	7.38	5519	3863	371	254.9	360	2.5	2281	134	362.5	65	1977
13	7.49	2175	1305	190	67	93	1.67	611.2	200	114	45	749
14	7.4	3397	2208	186	198.8	140	2.85	1061	262	307.8	52	1282
15	7.35	3232	2101	174	151.8	160	2.81	1066	270	228	49	1058
16	7.43	5535	3930	246.9	265	513	5.02	2096	274	421.8	89	1711
17	7.61	1823	1094	100	79.2	73	1.76	457.8	222	136.8	33	575
18	7.42	8487	7214	561	491.4	810	4.16	4679	215	262.2	124	3432
19	7.23	3748	2436	296	149.3	180	3.53	1251	210	291	55	1353
20	7.18	5637	4228	370	240.1	503	3.71	2502	216	285.6	61	1915
21	7.42	1935	1161	124	66.5	105	2.53	544.9	180	111.7	37	582.3

Table 4- Comparison average ionic concentrations with the standards of water quality(ppm)

parameter	**Standards**		**Dry period**		**Wet period**	
	IQS 2009	**WHO 2007**	**Range**	**Average**	**Range**	**Average**
pH	6.5-8.5	6.5-8.5	6.95-7.56	7.28	7.08-7.7	7.41
EC	1500	1530	1407-7306	3371	1600-8487	3600
TDS	1000	1000	816-5845	2261	928-7214	2475
Ca^{+2}	150	75	55.68-238.6	117.96	100-561	220.7
Mg^{+2}	100	125	52.07-576.4	177.85	50.4-491.4	157.9
Na^{+}	200	200	101.8-754.9	255.17	66-810	249.7
K^{+}	12	12	1.69-5.57	2.99	1.67-5.02	2.81
HCo_3	200	200	150-310	210.7	134-327	218.9
SO_4^{-2}	400	250	274.5-3802	1222.9	360.1-4679	1356.2
Cl^{-}	350	250	84-690	221.1	46.39-588.9	208.4
NO_3^{-}	50	50	13-165	49.4	33-124	52.3
TH	500	500	353-2904	1027	481-3432	1201.2
Fe	0.3	0.3	0.046-0.676	0.162		
Cu	1	1	0.001-0.007	0.004		
Pb	0.01	0.01	0.0-0.02	0.013		
Ni	0.02	0.02	0.002-0.018	0.006		
Co	---	0.05	0.0-0.012	0.004		
Zn	3	3	0.002-0.283	0.03		
Cd	0.003	0.003	0.0-0.001	0.0002		
Mn	0.1	0.1	0.001-0.046	0.008		

Table 5- Classification of water salinity according to (TDS) in (ppm) [19]

Water class	**Todd (2007)**	**Dry period**	**Wet period**
Fresh Water	**0−1000**	w3, w6, w8, w17	w3, w6
Slightly Brackish water	**1000–10000**	All remaining wells	All remaining wells
Brackish water	**10000−100000**		
Brine Water	**>100000**		

Table 6- Classification of water based on the total hardness [22] and [23]

Boyd (2000)		Driscoll (2009)	
T.H(ppm)	**Water quality**	**T.H(ppm)**	**Water quality**
T.H≤ 50	Soft	T.H < 9	Soft
50< T.H ≤ 150	Moderately hard	9 − 60	Slightly hard
150< T.H ≤ 300	Hard	60 −120	Moderately hard
T.H > 300	Very hard	120 −180	Hard
……	……	T.H >180	Very hard

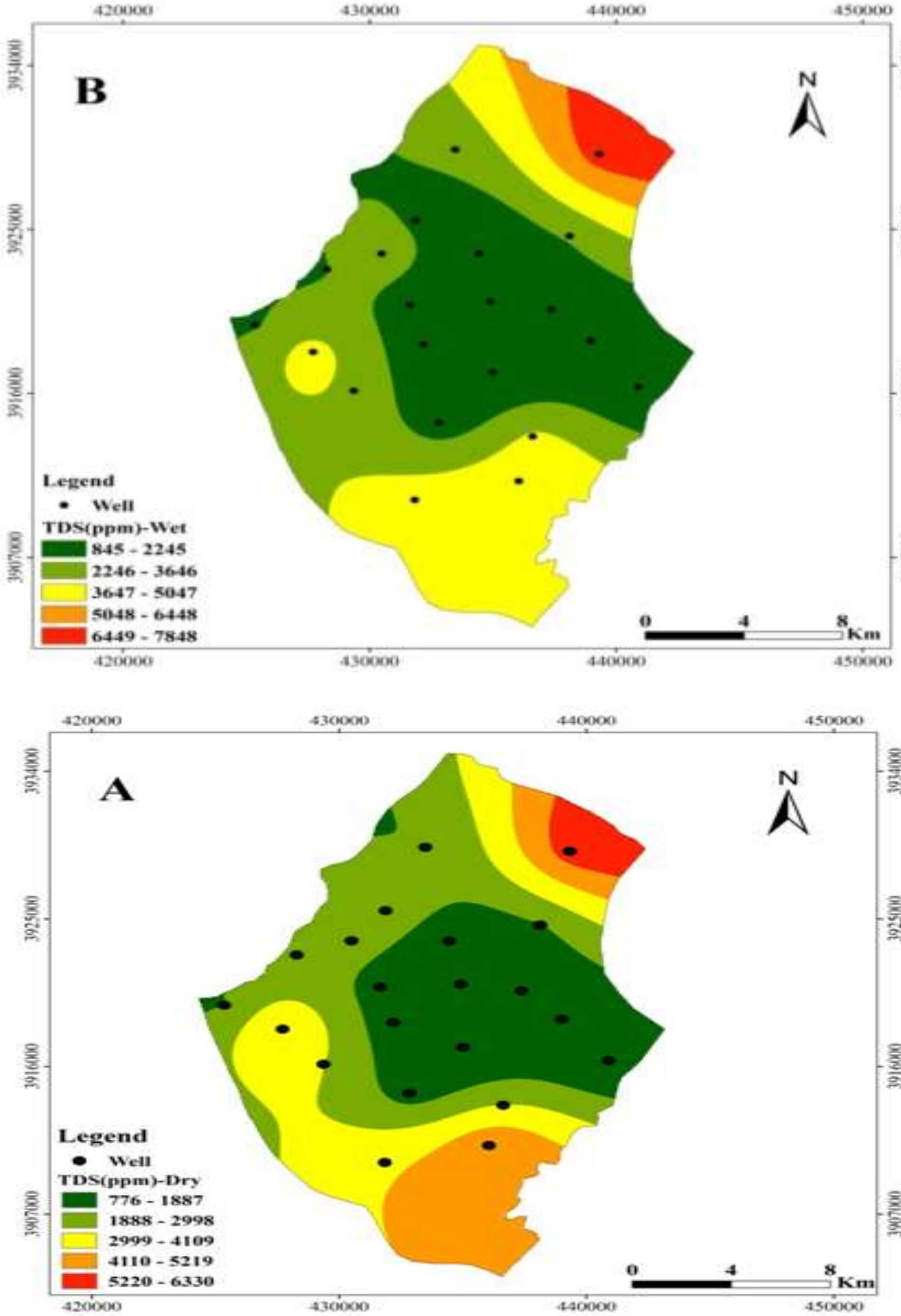

Figure 2-The spatial distribution of TDS concentrations in dry (A) and wet (B) periods
Hydrochemical properties of groundwater:

1. Hydrochemical formula (Kurolov formula)

An average of hydro chemical formula for two periods is shows presence three the predominant salts in the studied area such as $MgSO_4$ by ratio 57% in 12 wells and Na_2SO_4 by ratio 43% for 9 wells in the dry period, while $MgSO_4$ by ratio 38% in 8 wells, $CaSO_4$ by ratio 38% of 8 wells and Na_2SO_4 by ratio 24% in 5 wells in wet period.

2. Hydro chemical indicators

The rNa^+/rCl^- ratio is considered to one of the most important guides in determining the origin of groundwater. If the value of this ratio greater than 1 the water is meteoric origin, and less than 1 is marine origin [24]. Average values this indicator for both periods were ranged between 1- 3.65 with average 1.89 as shown in Table-7, where refer the values to greater than one this means all samples are meteoric water origin.

Table 7-Average values of (rNa^+/rCl^-) indicator of studied samples for both periods, (epm)

w.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
rNa/rCl	1.745	1.935	1.945	2.115	2.2	1.515	3.21	1.47	1.265	3.33	1.69	1.4	1.375	1.15	1.26	1.515	1	3.175	1.22	3.645	1.45

Heavy metals

Rocks and soils are the principal natural sources of heavy metals in the environment. Sources of heavy metals in the atmosphere are mineral dusts, sea salt particles, volcanic aerosols, forest fires, and industrial sources such as coal combustion [25]. Eight trace elements (Fe, Cu, Pb, Ni, Co, Zn, Cd and Mn) of groundwater samples were analyzed in the area and then compared with the WHO[17] and IQS[18] standards, as in Table-4 which shows that the concentrations all of trace elements falls within limits permissible for drinking water purposes except Fe and Pb in the wells (5,10,16) and (1,2,7,10,12,14,21) respectively, may be owing agricultural activities and weathering of clay minerals in the Quaternary deposits which cover the area, in addition to exist industrial area, Table-8.

Table 8- Concentrations of heavy metals in water samples of the study area by unit (ppm)

Well No.	Fe	Cu	Pb	Ni	Co	Zn	Cd	Mn
1	0.12	0.003	0.02	0.012	0.001	0.006	0.001	0.01
2	0.046	0.003	0.02	0.002	0.003	0.007	Nil	0.002
3	0.082	0.002	0.01	0.003	0.001	0.077	0.001	0.005
4	0.094	0.007	Nil	0.018	0.005	0.02	0.001	0.046
5	0.379	0.001	0.01	0.007	0.004	0.003	0.001	0.004
6	0.11	0.003	0.01	0.004	Nil	0.016	Nil	0.005
7	0.167	0.005	0.02	0.005	0.004	0.283	Nil	0.01
8	0.09	0.004	0.01	0.004	0.001	0.009	Nil	0.003
9	0.077	0.005	0.01	0.009	0.003	0.006	Nil	0.004
10	0.676	0.005	0.02	0.009	Nil	0.035	Nil	0.017
11	0.056	0.005	0.01	0.006	0.009	0.003	Nil	0.003
12	0.209	0.004	0.02	0.004	0.001	0.003	Nil	0.01
13	0.057	0.004	0.01	0.003	0.003	0.002	Nil	0.002
14	0.069	0.004	0.02	0.009	0.003	0.011	Nil	0.001
15	0.216	0.002	0.01	0.008	0.007	0.016	Nil	0.005
16	0.306	0.003	0.01	0.006	0.012	0.007	Nil	0.016
17	0.062	0.004	0.01	0.006	0.008	0.003	Nil	0.005
18	0.268	0.004	0.01	0.004	0.004	0.005	Nil	0.004
19	0.082	0.004	0.01	0.003	0.011	0.013	Nil	0.007
20	0.177	0.003	0.01	0.005	0.009	0.11	Nil	0.008
21	0.06	0.004	0.02	0.003	0.004	0.005	0.001	0.007

Groundwater Classification

According to Piper trilinear diagram [26], all water samples fall within the class (e) for both periods, while the samples (4, 9, 14) of the wet period fall in the class (c), Table-9. It is evident that the water samples for both periods is earth alkaline water with increase portion of alkali with prevailing sulfate and chloride, while three samples classified as normal earth alkaline water with prevailing sulphate or chloride in the wet period, as shown in Figures-(3A, 3B).

Table 9- Piper diagram divisions according to [27]

Primary title	Secondary title	Class	Dry period	Wet period
Normal earth alkaline water	With prevailing bicarbonate	**a**		
	With prevailing bicarbonate and sulphate or chloride	**b**		
	With prevailing sulphate or chloride	**c**		w4, w9, w14
earth alkaline water with increase portion of alkali	With prevailing bicarbonate	**d**		
	With prevailing sulphate and chloride	**e**	All samples	The samples residual
Alkaline water	With prevailing bicarbonate	**f**		
	With prevailing sulphate and chloride	**g**		

Groundwater suitability

The use of groundwater for the different purposes is determined (industrial, agricultural and livestock) by depending on the quality of water and its chemical elements.

***Groundwater suitability for human drinking purposes**

The water used for drinking purposes should be devoid of taste, color and turbidity and also from microorganism and compared the ionic concentrations of hydro chemical parameters with the guidelines prescribed by the [17] and [18] for determining the groundwater suitability for drinking. That the average concentrations all hydrochemical parameters are exceeded permitted limits except potassium ion (K) and Chloride ion (Cl), while all trace elements fall within their permitted limits except Lead (Pb) as shown in Table-4. Generally, that the groundwater in the study area is unsuitable for human drinking purposes, Table-4.

***Groundwater suitability for livestock purposes**

All studied samples are suitability for livestock purposes where the range between excellent and good type except samples (w1, w18) in the dry period and (w18) in the wet period according to [28], Table-10.

***Groundwater suitability for agriculture purpose**

According to the classification proposed by [19] as shown in Table-11 it is clear the all water samples of the study area for two periods are suitable for growing most types of crops.

***Groundwater suitability for building purposes**

Comparison of average of ionic concentrations of groundwater samples with the classification of [28], shown that the all samples for two periods in the study area are suitable for building purposes, Table-12.

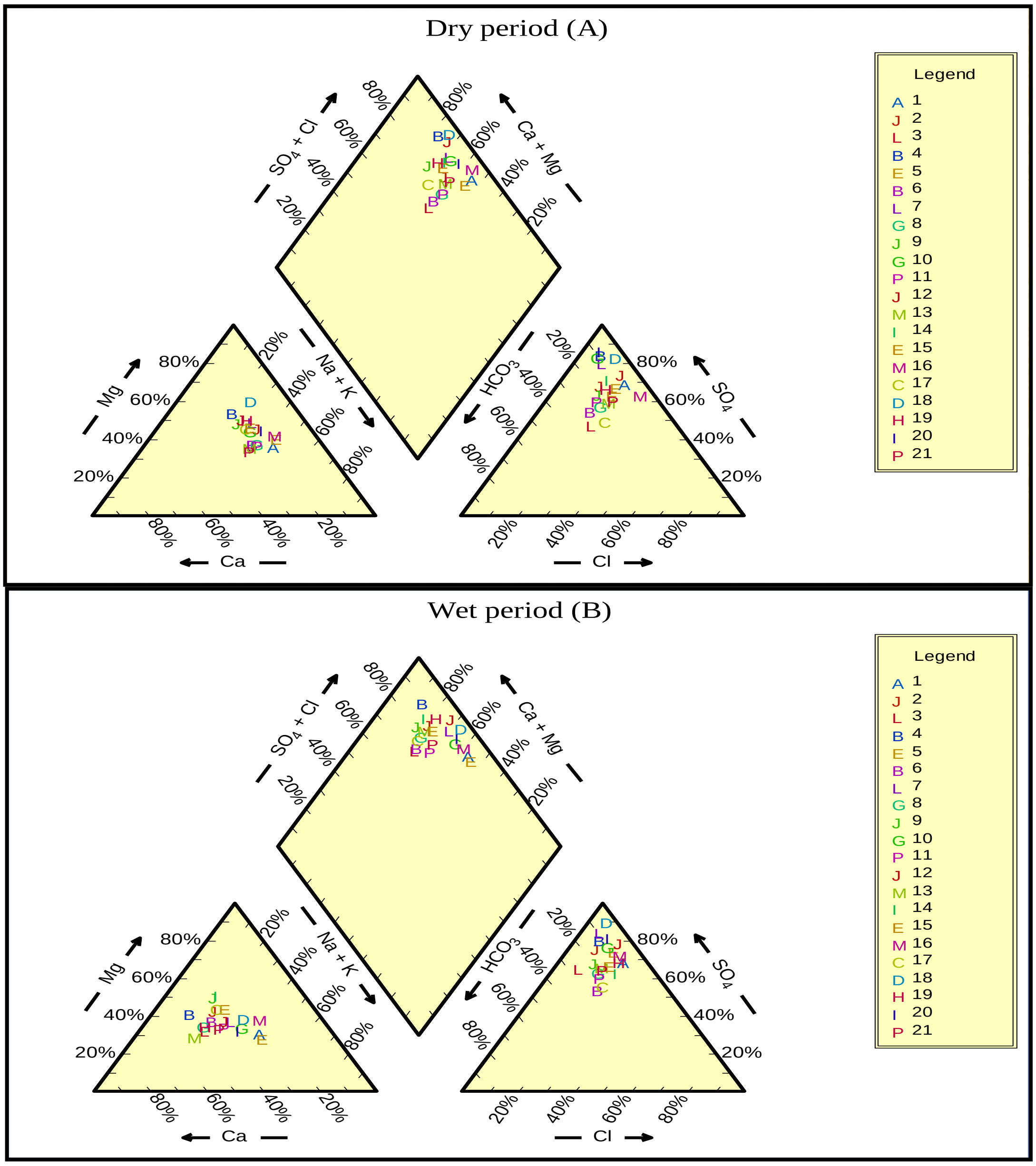

Figure 3-Piper classification of water samples of study area (A) Dry period (B) Wet period

Table 10-Water specifications for the purpose of animal consumption [28].

Sutability / parameter	Excellent type (ppm)	Good type (ppm)	Permissible type (ppm)	Able use (ppm)	Maximam Limit(ppm)	Average of two periods
TDS	3000	5000	7000	10000	15000	2368
Ca+2	350	700	800	900	1000	169.33
Mg+2	150	350	500	600	700	167.88
Na+	800	1500	2000	2500	4000	252.44
SO4−2	1000	2500	3000	4000	6000	1289.6
Cl−	900	2000	3000	4000	6000	214.75
TH	1500	3200	4000	4700	5400	1114.1
Wells of dry period	2,3,5,6,8,9, 11,13,15,17, 19,21	4,7,10,12, 14,16,20	1	18		
Wells of wet period	2,3,6,8,9,11, 13,17,21	1,4,5,10,12,14 ,15,16,19,20			18	

Table 11- Relative tolerances of crops to salt concentrations for agriculture [19]

Crop Division	Low Salt Tolerance EC (µS /cm)	Medium Salt Tolerance EC (µS /cm)	High Salt Tolerance EC (µS /cm)
Fruit Crops	**0-3000 Lemon, Strawbrry, Peach Spricot, Almond, Plum, Orange, Apple, Pear.**	**3000-4000 Cantaloupe, Olive, Fig Pomegranate.**	**4000-10,000 Date palm.**
Dry period	**Wells, 2,3,6,8,9,11,13,15,17,21**	**5,7,14,19**	**1,4,10,12,16, 18,20**
Wet period	**Wells, 2,3,6,8,9,11,13.17,21**	**4,14,15,19**	**1,5,7,10,12,16, 18, 20**
Vegetable Crops	**3000-4000 Green beans, Celery, Radish.**	**4000-10,000 Cucumber, Peas, Onion Carrot, Potatoes, Sweet Corn, Lettuce, Bell, Cauliflower, pepper, Cabbage, Broccoli , Tomato.**	**10000-120,000 Spinach, Garden beets**
Dry period	**Wells, 5,7,14,19**	**1,4,10,12,16,18,20**	**---**
Wet period	**Wells, 4,14,15,19**	**1,5,7,10,12,16,18,20**	**---**
Field Crops	**4000-6000 Field beans.**	**6000-10,000 Sunflower, Corn (field) Rice, Wheat, (grain).**	**10,000-16,000 Cotton, Sugar beet Barley (guain).**
Dry period	**Wells, 4,10,12,16,20**	**1, 18**	**---**
Wet period	**Wells, 5,7,10,12,16,20**	**1, 18**	**---**

Table 12- Evaluation of water for building uses according to [28]

Ions	Permissible Limit	Dry period	Wet period
Ca^{2+}	**437**	117.96	220.7
Mg^{2+}	**271**	177.85	157.9
Na^{+}	**1160**	255.17	249.7
HCO_3^{-}	**350**	210.7	218.7
SO_4^{2-}	**1460**	1222.9	1357.2
Cl^{-}	**2187**	221.1	208.2

Groundwater suitability for irrigation purposes

Increasing of EC in the irrigation water leads to decrement in plant growth and crop production in addition increment of chloride cause burns of tree leafs especially citrus trees and grape. While increasing of sulphate causes an increase of SAR, which effects plants growth [29]. Values of parameters influencing in suitability of groundwater for irrigation purposes shown in the Table-13.

***Salinity**

Increments of TDS and EC in irrigation water will affect the soil structure, permeability and aeration, therefore affect the plant growth. Soil water passes into the plant through the root zone due to osmotic pressure. These effects are visible in plants by stunted growth, low yield, discoloration and cause burns of tree leaves [30]. All water samples fall within bad and very bad categories by ratio 61.9%, except samples (3,6,8,9,11,13,17,21) in the medium category by ratio 38.1% for both periods, Tables-(2, 3). Therefore, not safe for irrigation purposes according to [29], Table-14.

Table 13- Values of (EC, SAR, Na%, RSC and MAR) for all water samples by (meq/l).

Well No.	Dry period				Wet period			
	SAR	**Na%**	**RSC**	**MAR**	**SAR**	**Na%**	**RSC**	**MAR**
1	7.57	46.66	-32.65	68.44	6.62	43.93	-30.63	55.60
2	2.85	36.34	-9.28	72.68	1.55	21.97	-12.49	55.07
3	2.35	38.83	-3.59	60.69	1.37	24.11	-6.23	43.04
4	2.41	23.05	-29.48	70.45	1.11	13.89	-21.64	48.11
5	4.65	45.45	-12.53	74.81	5.47	46.34	-16.90	52.41
6	2.45	38.57	-4.48	61.25	1.36	23.53	-6.69	49.32
7	3.34	32.87	-20.06	73.60	3.45	30.75	-26.93	54.57
8	2.60	39.58	-5.06	63.24	1.34	22.00	-8.47	44.68
9	1.87	27.68	-8.83	67.54	1.13	18.34	-9.57	61.56
10	3.69	33.82	-22.00	67.85	4.29	35.85	-25.27	53.28
11	2.96	40.28	-6.23	62.59	1.92	29.55	-7.33	49.28
12	3.12	28.40	-28.86	71.06	3.52	28.47	-37.30	53.11
13	2.65	38.01	-6.47	58.36	1.48	21.42	-11.69	36.77
14	3.30	33.57	-17.65	69.97	1.70	19.38	-21.32	63.79
15	3.04	33.34	-14.81	69.84	2.14	24.93	-16.73	59.00
16	5.82	43.62	-25.87	75.30	5.49	40.04	-29.69	63.91
17	2.05	32.04	-6.24	67.88	1.32	21.87	-7.85	56.63
18	3.85	26.46	-55.02	81.92	6.03	34.05	-65.06	59.09
19	2.56	29.95	-14.21	72.17	2.13	22.64	-23.59	45.39
20	5.02	39.13	-27.41	74.28	5.02	36.57	-34.73	51.69
21	2.89	39.18	-7.49	56.16	1.89	28.43	-8.69	46.93

*__Sodium Adsorption Ration (SAR)__

SAR is a measurement of the ratio of sodium (Na+) ions for calcium (Ca+2) and magnesium (Mg+2) ions, expressed by meq/1. If SAR is more than 9 this means an increase of sodium or reduction in content of calcium plus magnesium in the groundwater, it can cause a dispersion of soil colloids, destroying soil texture and high permeability [31]. SAR values of water samples in the area are less from 9 for both periods as shown in Table-13, where indicate to that the all samples falls within the category of excellent according to [29], Table-14. Evaluate the SAR by using the following formula [19]:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where the ion concentrations are expressed in equivalent per million(epm).

***Soluble Sodium Percentage (Na%)**

Can calculate Na% by using the equation [32] below:

$$\textbf{Na \%} = \frac{\mathrm{Na+K}}{\mathrm{Ca+Mg+Na+K}} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Where the ion concentrations are expressed in equivalent per million (epm).

Sodium percentage values in samples of the study area Table-13, shows that all the water samples within the good category except samples (1,5,11,16) in the medium class for the dry period, while in the wet period, most of them were found within the good category except samples (4,9,14) that located in the excellent class, and (1,5,16) within the medium category according to classification [29] as shown in Table-14.

***Residual Sodium Carbonate (RSC)**

It calculated according to the following equation [33]:

RSC = ($[CO_3^{2-}] + [HCO_3^-]$) - ($[Ca^{2+}] + [Mg^{2+}]$) (epm) …………………………………………...(3)

RSC values of all water samples in the study area for both periods were an adverse values as shown in Table 13. As evident all water samples fall within excellent and non hazard category, according to [29], Table-14.

***Magnesium Adsorption Ratio (MAR)**

High MAR values in the irrigation water cause a harmful effect to soil when it exceeds 50%, while Magnesium of Ratio less than 50% is suitable for irrigation purposes [34]. Can be calculated by the equation [35] as:

$$\mathbf{MAR} = \frac{\mathbf{Mg}}{\mathbf{Mg+Ca}} \times \mathbf{100} \qquad \text{…………………………………(4)}$$

Where, all the ionic concentrations are expressed in meq/L.

MAR values of water samples in the study area of both periods are more than 50% means that all samples not suitable for irrigation purposes, except samples (3,4,6,8,11,13,19,21) of the wet period only, which represent ratio 38% , as shown in the Table-13.

Table 14- Guidelines for evaluation of irrigation water quality [29]

EC µs/cm	SAR(meq/l)	Na(%)	RSC(meq/l)	Water class
< 250	< 10	< 20	< 1.25	Excellent
250 − 750	10 − 18	20 − 40	1.25 – 2.0	Good
750 − 2250	18 −26	40 − 60	2.0 – 2.5	Medium
2250 − 4000	> 26	60 − 80	2.5 – 3.0	Bad
> 4000	> 26	> 80	> 3.0	Very bad

Conclusion

The average of chemical analysis results for the groundwater samples for the two periods shows that the water is low alkaline and has an excessively mineralized and most of it is classified as a Slightly Brackish water with some samples that are fresh water. Values of major cations and anions are higher than water quality standards, according to WHO,2007 and IQS, 2009 except K and Cl ions, that could be due to the impact of Fatha Formation rocks within Kirkuk structure as well as some industrial and agricultural activities. The water in the study area is devoid of heavy metal pollution except Fe, Pb in some wells, and may be due to some industrial activities. The predominant salts are $MgSO_4$, Na_2SO_4 and $CaSO_4$, and water types are "earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride" and "Normal earth alkaline water With prevailing sulphate or chloride". Groundwater in the study area is unsuitable for human drinking purposes, but it's suitable for building and livestock and for growing most types of crops, it is also not safe for irrigation purposes by salinity but suitable for irrigation purposes depending on SAR, Na% and the RSC, and unfit for irrigation according to (MAR) index.

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