Evaluation of Suitability of Drainage Water of Al-Hussainia sector (Kut-Iraq) For Irrigation

BY

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Abstract

Al-Hussainia sector is the middle sector of Al-Dalmaj irrigation project. In this study, a specified area of Al-Hussainia sector has been selected to be evaluated for its water suitability for irrigation. For Al-Hussainia main drain, the evaluation includes four stages as follows:
1- Chemical evaluation of drainage water, 2-Analysis of drainage water by Aq.Qa software, 3- Leaching requirements computations, 4- Evaluation of the drainage water quality in the specified area of the project using the Geographic Information System (GIS) software. For the chemical evaluation, the most important indicators for the salinity problem considered are (Electrical Conductivity, Total Dissolved Solids, Sodium Adsorption Ratio and Sodium Content). The test results showed that there are no harmful effects from Sodium indicators on crops production while there is a salinity problem. The residual sodium carbonate values were zero for all locations. The analysis of the hydro chemical results by Aq.Qa program shows that the internal consistency of the samples was acceptable. It is concluded that the drainage water of Al-Hussainia sector can be used directly to irrigate wheat and barley without reducing the yield with leaching requirement of 0.25 for wheat for all locations while barley needs a leaching requirement of 0.15 for locations 3,4, and 5 a leaching requirement of 0.17 should be provided for locations 1, 2, and 6. For corn crop, the drainage water is unsuitable for irrigation unless it is mixed with irrigation water to eliminate the salinity hazard. However the mixing ratio is0.5 (1:1) for all locations except location 2 where the mixing ratio needed is0.6 (1:2). The three dimensional spatial analysis using the GIS software (Arc Map V. 9.3) showed that the final model of the study area is of permissible irrigation water quality.

الخلاصة

قطاع الحسينية هو القطاع الوسطي لمشروع الدلمج الاروائي.
في هذه الدراسة مساحة محددة من قطاع الحسينية تم اختيارها لتقييم صلاحية مياهها للري. للمبزل الحسينية الرئيسي تضمن التقييم اربعة مراحل كالاتي:
1-التقييم الكيميائي لمياه المبزل، 2-تحليل مياه البزل بواسطة برنامج Aq.Qa، 3-حسابات متطلبات الغسل للتربة، 4-تقييم نوعية مياه المبزل لمنطقة معينة من المشروع باستخدام برنامج نظم المعلومات الجغرافية (Arc GIS Map V. 9.3). للتقييم الكيميائي ان المؤشرات الاكثر اهمية لملوحة التربة هي (الموصلية الكهربائية، المواد الصلبة الكلية الذائبة، نسبة امتزاز الصوديوم و كاربونات الصوديوم المتبقية). بينت نتائج الفحوصات بانة لا توجد مشكلة الصودوية بينما هناك مشكلة ملوحة وكانت قيمة كاربونات الصوديوم المتبقية صفر لجميع المواقع. بين تحليل النتائج ببرنامج Aq.Qa ان التجانس الداخلي للعينات كان مقبولا.

تم الاستنتاج بانه يمكن استخدام مياه مبزل الحسينية الرئيسي لري النباتات المزروعة في المنطقة(الحنطة ،الشعير والذرة) بشكل مباشر وبدون التاثير على الإنتاجية مع متطلبات غسل مقدارها 0.25 للحنطة ولجميع المواقع بينما يحتاج الشعير الى متطلبات غسل مقدارها 0.15 للمواقع 3,4 و 5 ومتطلبات غسل مقدارها 0.17 للمواقع 1,2 و 6. لمحصول الذرة مياه المبزل غير ملائمة للري إلا اذا تم خلطها مع مياه خام للتخلص من الملوحة. على اية حال ان نسب الخلط هي 0.5 لجميع المواقع عدا الموقع رقم 2 حيث ان نسبة الخلط هي 0.6. برنامج نظم المعلومات الجغرافية بين ان الموديل النهائي كان ضمن تصنيف (مسموح) .

Introduction

The Second World Water Forum in the Hague in March 2000 noted that water will be one of the central issues of the 21st century in the globe, and thus the life of billions of people will depend on its wise management. Water is an essential and basic human need for urban, industrial and agricultural use and has to be considered as a limited resource. In this sense, only 2.5% of the total water resources in the world can be considered as fresh water, in 2025 nearly one-third of the population of developing countries, some 2.7 billion people, will live in regions of severe water scarcity. Since the agricultural sector uses usually about 80%of the available water resources for crop production, then, in areas where irrigation water is scarce water reclamation and reuse have become an attractive option for conserving and extending available water supply. **[1].** Project evaluation is a step-by-step process of collecting, recording and organizing information about project results, including short-term outputs (immediate results of activities) and longer-term project outcomes (changes in behavior, practice or policy resulting from the project). Project evaluation is used to conduct a systematic and comprehensive assessment of the relevance, performance and impact of the project in the context of its stated objectives. This means, it reviews the relevance of the project to solve the identified problems. It also makes analysis of the project inputs, activities and results and compares these with the designed bases. The results are used to adjust the planning or implementation strategy to ensure the required project results. **[2].** The aim of this study is to make evaluation for a specific area of Al-Dalmaj project/Al- hussainia sector. The evaluation program involves the effect of salinity on crops production, computing the leaching requirements, finding the mixing ratios and use the GIS software (Arc map V.9.3) to evaluate the drainage water quality in the specified area of the project.

1- Project Description

The study was conducted in Al-Dalmaj project/ Al- hussainia sector. It is located between 45◦ 28' to 45◦ 45' eastern longitude and 32◦ 28' to 32◦ 10' northern latitude. The project area covers 59 382 hectares (237528 donums) and extends about 33.3 km from north to south and 28.3 km from west to east, at its broadest. Al-Hussainia sector was constructed in 1974 and it is located between 45◦ 39' to 45◦ 45' eastern longitude and 32◦ 28' to 32◦ 10' northern latitude. The project area covers 25237.25 ha (100949 donums) with total length of 34.2 km and extends about 29 km from north to south and 12.5 km from west to east, at its broadest. the area that Al-Hussainia sector serving is bounded from the west by Al-Hussainia main canal ,and by Al-mazzaq main canal from the east. Ground elevations in the area vary between 16.15 to11.45. Figure (1) shows the site plan of Al-Dalmaj project. **[3]**.

Figure (1): site plan of Al-Dalmaj project (Wasset \Kut city). [3]

1- The Chemical Evaluation

The criteria used to evaluate the quality of drainage water for use in agriculture are 1)salinity of irrigation water for salt built up in soils and its adverse effect on plant growth ,2)Sodium Adsorption Ratio(SAR) for its deleterious effect on soil physical properties ,3)Residual Sodium Carbonate(RSC) for its effect on final soil water SAR value with the loss or gain in Ca and Mg concentrations due to the precipitation or dissolution of alkaline earth carbonate and 4)Toxic Effects of specific Ions in irrigation water such as Na ,Cl ,SO_4 and B on plant growth and yield. [4]

Besides the above indicators, some mathematical equations and models were applied to evaluate the water quality for its reuse in irrigation in Al-Hussainia sector.

Sodium Adsorption Ratio is defined by [5]:

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

the Residual Sodium Carbonate equation is :

$$\mathbf{RSC} = (\mathbf{CO3}^{-2} + \mathbf{HCO_3}^{-}) - (\mathbf{Ca}^{+2} + \mathbf{Mg}^{+2}) \ldots \ (2)$$

Where all concentrations of the constituents are expressed in (mg/l).

Table (1) shows the classification of irrigation water according to SAR. , table (2) shows the classification of irrigation water according to Residual Sodium Carbonate.

Table (1) Classification of irrigation water based on SAR values. [6]

Level	SAR	Hazard
S1	<10	No harmful effects from sodium.
S2	≥10–<18	An appreciable sodium hazard in fine-textured soils but could be used on sandy soils with good permeability.
S3	≥18–<26	Harmful effects could be anticipated in most soils and amendments such as gypsum would be necessary to exchange sodium ions.
S4	≥26	Generally unsatisfactory for irrigation.

Table (2) Potential for precipitation of calcium and magnesium at the soil surface by high carbonate and bicarbonate in the irrigation water as determined by Residual Sodium Carbonate (RSC) equation. [7]

RSC Value (meq/l)	Potential Use
≤1.25	Generally safe for irrigation.
1.25 to 2.5	Marginal as an irrigation source.
>2.5	Usually unsuitable for irrigation without amendment.

High salts can reduce or even prohibit crops production and can reduce water infiltration, which indirectly affect the crops. An understanding of the quality of water used for irrigation and its potential negative impacts on crop growth is essential to avoid salinity problems . Water quality and soil chemical analyses are necessary to determine which type of salts are present and the concentrations of these salts. **[9]**
For the chemical evaluation ,six samples were taken from six locations of Al-Hussainia main drain (from july 2012 to February 2013). Locations of the samples are marked by the green points as shown in Figure (2).

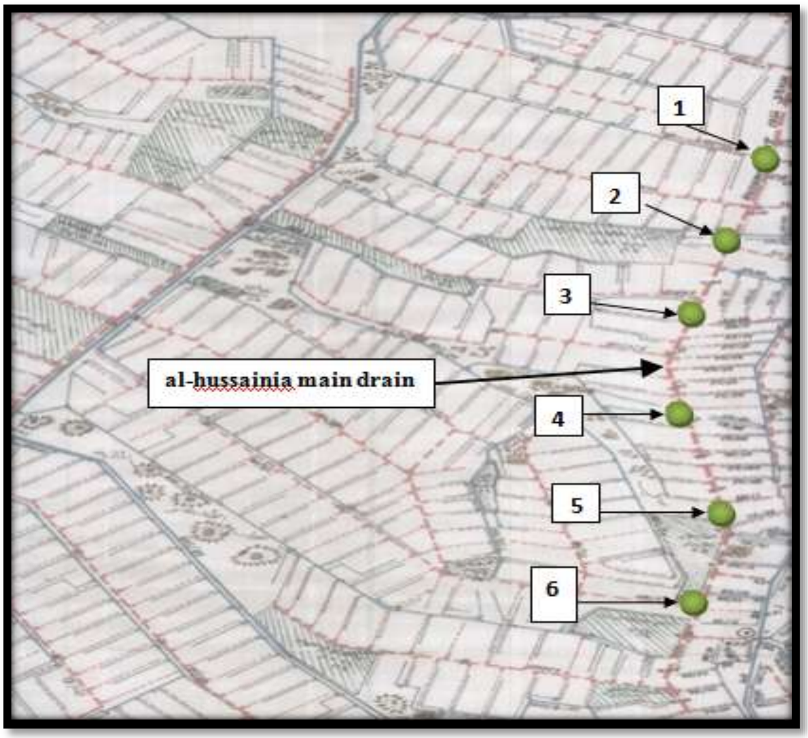
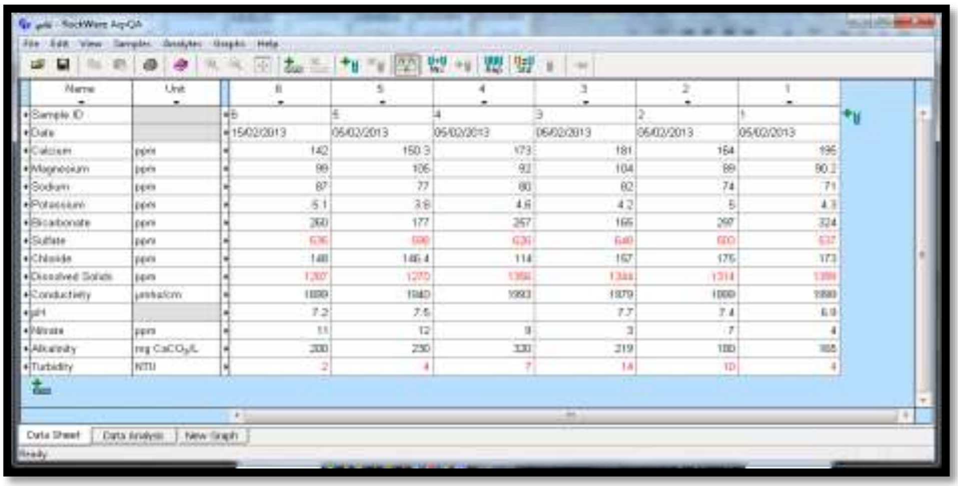


Figure (2) Locations of taking the samples in Al-Hussainia main drain

To evaluate the quality of drainage water Rock ware Aq.Qa [the spreadsheet for water analysis] version1.1.1 [1.1.5.1] was used as shown in Figure (3).



Name	Unit	6	5	4	3	2	1
Sample ID		6	5	4	3	2	1
Date		15/02/2013	05/02/2013	05/02/2013	05/02/2013	05/02/2013	05/02/2013
Calcium	ppm	142	150.3	173	181	164	195
Magnesium	ppm	99	106	92	104	89	90.2
Sodium	ppm	87	77	80	82	74	71
Potassium	ppm	5.1	3.8	4.6	4.2	5	4.3
Bicarbonate	ppm	260	177	257	165	297	324
Sulfate	ppm	636	[illegible]	626	640	[illegible]	637
Chloride	ppm	148	146.4	114	167	175	173
Dissolved Solids	ppm	1,207	1270	[illegible]	1344	1314	[illegible]
Conductivity	µmho/cm	[illegible]	1940	1993	1879	[illegible]	[illegible]
pH		7.2	7.5		7.7	7.4	6.9
Nitrate	ppm	11	12	9	3	7	4
Alkalinity	mg $CaCO_3$/L	200	230	330	219	180	165
Turbidity	NTU	2	4	7	14	10	4

Figure (3) Window of entering the data of the six locations in February 2012 by using the Aq.Qa Software

4-Strategies of Using Drainage Water

Two strategies will be discussed for utilizing Al-Hussainia main drain's saline water in irrigate the main corps that planted in the study area, namely (Wheat ,Barley and Corn) these Strategies are cyclic and blending**.**

4-1 Cyclic

Saline drainage water is used solely for certain crops and only during certain portions of their growing season. The objective of the cyclic strategy is to minimize soil salinity during salt-sensitive growth stages, or when salt-sensitive crops are grown. With a cyclic strategy, the soil salinity profile is purposefully reduced by irrigation with good quality water, Thereby facilitating germination and permitting crops with lesser tolerances to be included in the rotation. The cyclic strategy keeps the average soil salinity lower than that under the blending method, especially in the upper portion of the profile, which is critical for emergence and plant establishment**. *[10].*** Drainage water can be used to irrigate crops directly using cyclic strategy ,but the accumulation of excess soluble salts in the root zone is a widespread problem that seriously affects crop productivity. To prevent the accumulation of excessive soluble salts in irrigated soils, more water than required to meet the vapor transpiration needs of the crops must pass through the root zone to leach excessive soluble salts. This additional irrigation water has typically been expressed as the leaching requirement (LR). To estimate the leaching requirement, both the irrigation water salinity (ECw) and the crop tolerance to soil salinity (ECe) must be known**. [11]**

The necessary leaching requirement (LR) can be estimated from Figure (4) for general crop rotations.

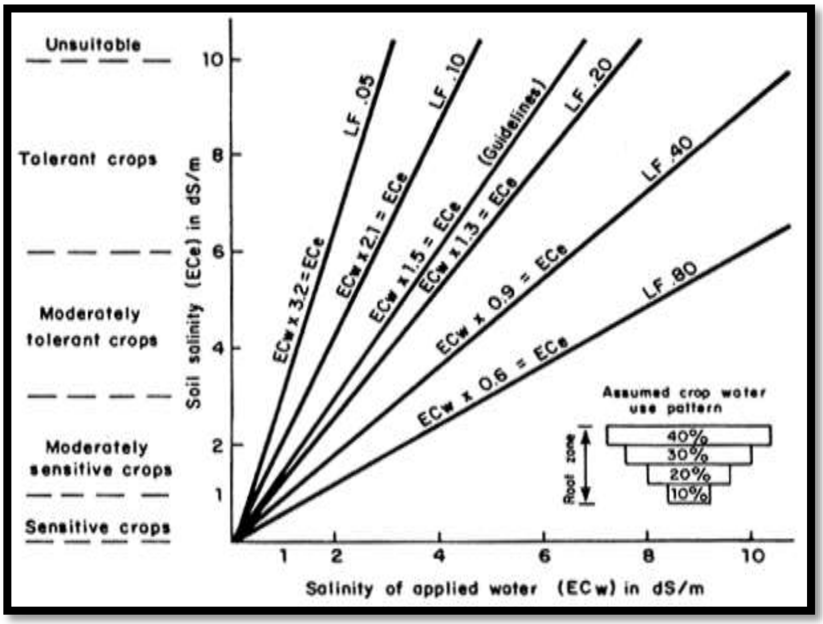


Figure (4) Effect of applied water salinity (ECw) upon root zone soil salinity (ECe) at various leaching fractions (LF)for 100% yield potential. [12]

For more exact estimates for a particular crop, the leaching requirement equation (3) should be used:

$$LR = \frac{EC_W}{5(EC_e) - EC_W} \text{.........} (3)$$

Where

LR: Leaching Requirements

ECw : Irrigation Water Electrical Conductivity.

ECe Soil Electrical Conductivity

In many texts, the Terms 'leaching fraction (LF)' and 'leaching requirement (LR)' are used interchangeably. They both refer to that portion of the irrigation, which should pass through the root zone to control salts at a specific level. While LF indicates that the value be expressed as a fraction, LR can be expressed either as a fraction or percentage of irrigation water. In this study, we used the term "leaching requirement ". **[8]**

4-2 Blending

Blending involves mixing saline water and good quality water together to achieve an irrigation water of suitable quality based on the salt tolerance of the chosen crop. Blending is not attractive if saline water does not supply at least 25 percent of the total irrigation water requirement. That is, the costs and risks of the increased management associated with adding salts to the irrigation supply will likely outweigh the benefits from increasing the total water supply by only a slight to modest amount. **[10]**

If we have two water resources the first one is (a) and the second is (b), the The quality of the blended water can be found by using equation (4.2):

$$\text{concentration of the blended water} = \left(\text{concentration of water(a)} * \text{proportion of water (a)used}\right) + \left(\text{concentration of water (b)} * \text{proportion of water (b)used}\right) \quad Eq\ldots(3)$$

where the concentration can be expressed as either ECw or ppm but the same units of concentration must be used throughout the equation. **[12]**

The mixing ratio can be found by equation (4):

$$\textit{mixing ratio} = \textbf{Drainage water} : \textbf{irrigation water} \ldots\ldots..(4)$$

in this research the drainage water was mixed with the irrigation water of Al-Mazzaq cannel which is the closest channel to the main drain. ***Al-Mazzaq cannel chemical analysis results are typed in table (3)***

Table (3) Average results of Al-Mazzaq cannel chemical analysis during the study period

pH	EC	TDS	Cl	SO_4	HCO_3	K	Na	Mg	Ca	SAR
7.59	1086	706.5	111.2	282.2	0.0	2.24	84.2	35.67	103.5	1.8

5-Evaluation of drainage Water Quality Using the GIS software

In this study, a specified area of Al-Hussainia sector was selected to be evaluated for its drainage water quality. The study area is located between 45◦ 33' to 45◦ 40' eastern longitude and 32◦ 24' to 32◦ 17' northern latitude. Ten samples of surface drainage water were taken from different ten locations of the study area in (15/7/2013). These locations are **(HU/0/10/7 L HU/0/10/18 R ,HU/0/8/5 L, HU/0/6/ 6R ,HU/2/3/3 L ,HU/2/4/14 R ,HU/2/ 1L,Collector 2/7 ,HU/2/1/13 L ,HU/0/8/15 L)** as shown in Figure (5).These samples were analyzed chemically for four indicators which effect irrigation water quality . These indicators are : Chloride(Cl^{-}) , Electrical Conductivity (EC) , Sodium Adsorption Ratio (SAR) and Sodium Content (Na%). The results of chemical analysis of drainage water of these locations are shown in Table (4).

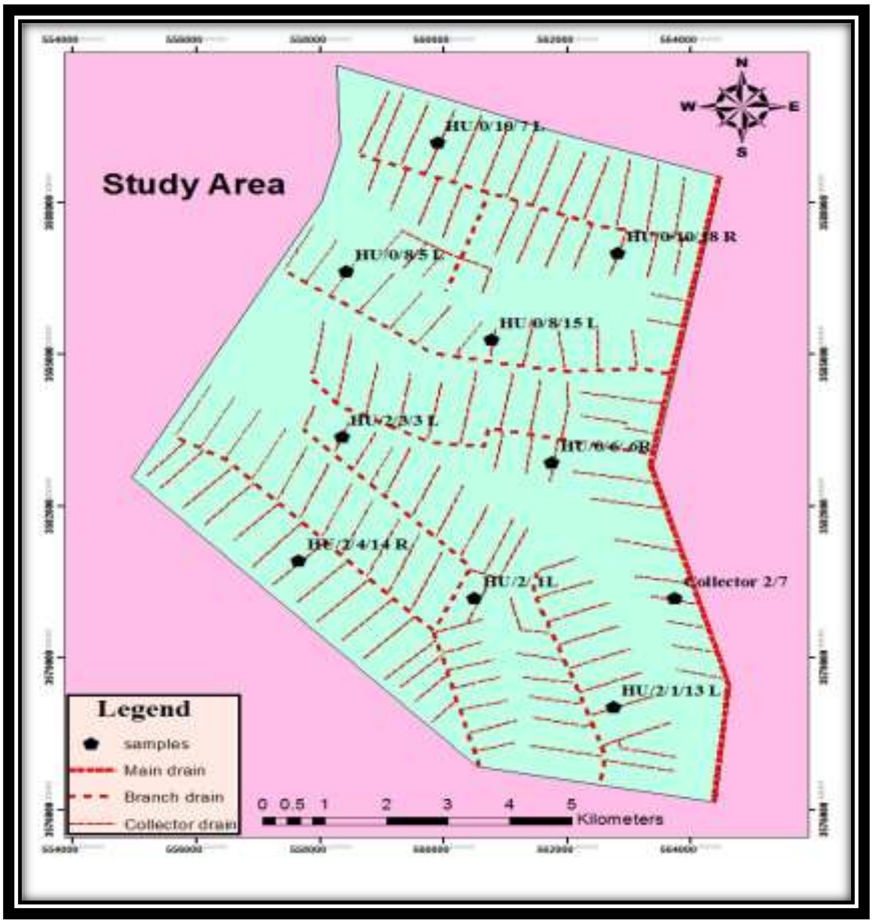


Figure (5) Locations of taking the samples in the study area

Table (4)the result of chemical analysis of drainage water for the analysis by the GIS software

Type / Location	Ca^{+2} ppm	Mg^{+2} ppm	Na^{+} ppm	K^{+} ppm	Cl^{-} ppm	EC µS/cm	TDS ppm	PH P^{H}	TH ppm	SO_4^{-2} ppm	alkalinity	HCO_3^{-} ppm	NO_3^{-} ppm
Collector 2/7	1100	666	1012	8.4	5300	2700	1935	7.78	1582	749	300	502	3.1
HU/0/10/18 R	1409	398	729	2.24	2530	4310	4124	7.9	2153.8	3452	300	277	6
HU/0/10/7 L	373.7	110	431	3	808	2350	1504	7.6	1385	978	400	182	3
HU/0/6/ 6R	211.2	128.8	287	1.2	650	2390	1625	7.69	1375	734.1	320	187	3
HU/0/8/15 L	625	81.2	184	4.1	840	3656	2194	7.7	1895	922	200	410	3.6
HU/0/8/5 L	1512.6	218	652	2.5	1140	5750	3910	7.6	2175	1644.4	260	305	4.2
HU/2/ 1L	1248.4	622	964	2	2730	3640	2582.4	7.43	1670	853	200	400	5
HU/2/1/13 L	1591.6	833.2	1031	4.6	4600	1860	1524	7.68	1293.7	935.6	280	257	2
HU/2/3/3 L	326.2	128	373	1.27	500	3500	2412	7.63	1340	1112.3	300	256	4.5
HU/2/4/14 R	483	158.6	395	1.97	627	5040	3496	7.79	1857.5	1504.4	300	401	7

5-1 Benefits of the GIS software

The GIS software was used in this study. Arc GIS provides tools to serve a purpose to create conceptual model for solving spatial problems. A set of conceptual steps can be used to build a suitable model to evaluate drainage water quality. Three dimensional spatial analyst of the GIS software can be interpolate the data of each concentrate factor (EC, SAR, Na% and Cl^{-}) into raster (groups of cells that share the same value represent geographic features). These rasters are reclassified by grouping ranges of values into single value. New output raster represents the mean value of the four rasters by making raster cell statistics to show the spatial extent of suitability of drainage water for irrigation. Four raster map layers were incorporated to produce the final suitable model to evaluate drainage water quality in the study area. ***[13]***Reclassifying data means replacing input cell values with new output cell values to create new rasters based on drainage water quality for irrigation. Cell statistics, in which the value at each location on the output raster is a function of the input values at the same location, is used to obtain the final suitability model to evaluate drainage water quality, computes the mean of the values on a cell-by-cell basis between input rosters ,as illustrated in Figure(6).

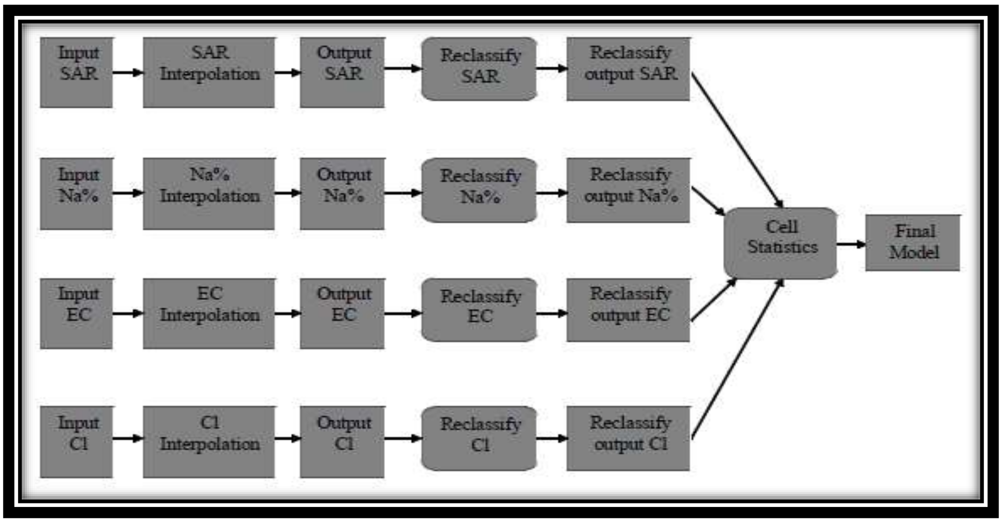


Figure (6) GIS modeling scheme

Figures from (7) to (10) are showing the distribution of these four indicators, which affect water quality for irrigation in this study.

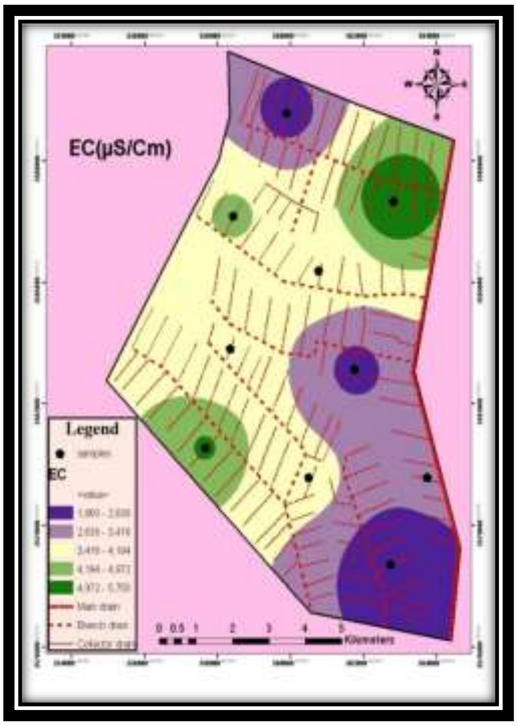


Figure (7) Distribution of EC in the study area

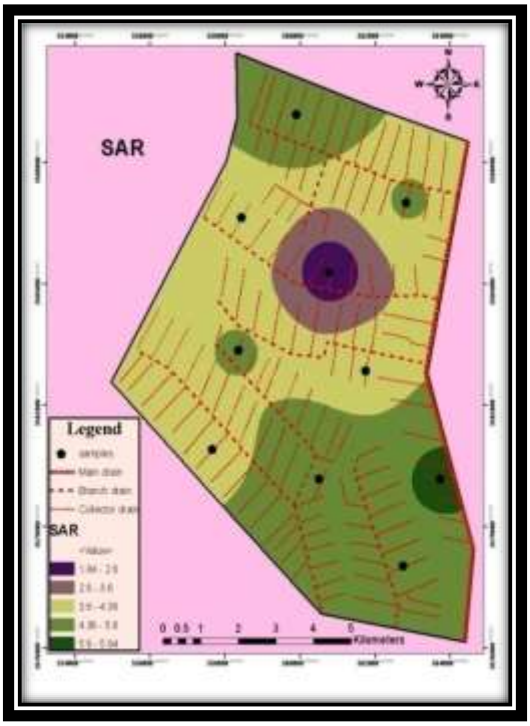


Figure (8) Distribution of SAR in the study area

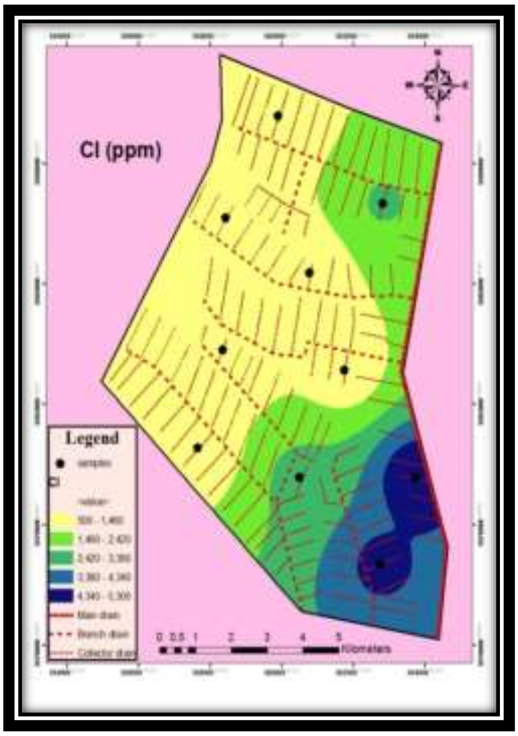


Figure (9) Distribution of Cl in the study area

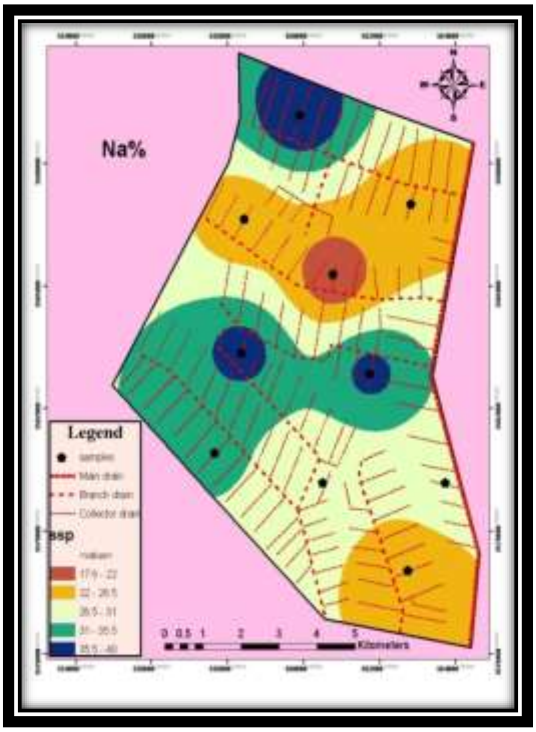


Figure (10) Distribution of Na% in the study area

5-2 Values Reclassified

Three Dimensional spatial analyst of the GIS software reclassifies a range of values into an alternative value. All values on the original raster that fall within the specified range of values will receive the alternative value assigned to that range, so new distributions for the constraint factors are based on the suitability of the mentioned elements for irrigation. The reclassified values of the four elements (EC, Na%, SAR and Cl^-) are shown in ***Figures from (11) to (14)***. Suitability value is classified water quality into preference categories using the chemical elements that affect most agricultural production. ***Table (5)*** shows the proposed suitability alternative values for the constraint factors which will be used in cell statistics. According to the new alternative values, new rosters were produced showing the distribution of each constraint factor spatially.

Table (5) Proposed suitability alternative value of most elements that affect irrigation water quality (Jawad, 2007)[14]

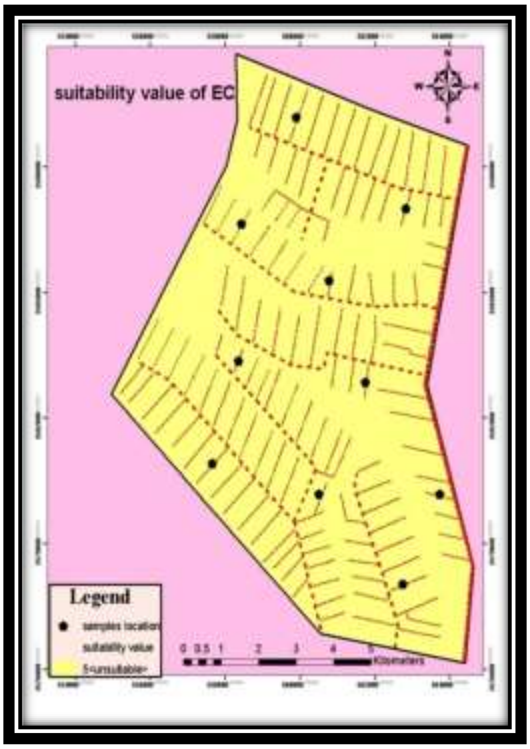
Element \ Suitable value	1.0	2.0	3.0	4.0	5.0
EC (µS/cm) *(Wilcox, 1955)*	**<250** **Excellent**	**≥250 - <750** **Good**	**≥750 - <2000** **Permissible**	**≥2000 - <3000** **Doubtful**	**>3000** **Unsuitable**
Na% *(Wilcox, 1955)*	**<20** **Excellent**	**≥20 - <40** **Good**	**≥40 - <60** **Permissible**	**≥60 - ≤ 80** **Doubtful**	**>80** **Unsuitable**
Cl (ppm) *(Westcot, 1985)*	**<150** **Excellent**	**≥150 - <250** **Good**	**≥250 - <500** **Permissible**	**≥500** **Doubtful**	**No data**
SAR *(Todd, 1980)*	**<10** **Excellent**	**≥10 - <18** **Good**	**≥18 - <26** **Permissible**	**No data**	**> 26** **Unsuitable**

5-3 Raster Statistics

Using the raster statistics to combine the four rosters into one raster that represent the final suitable model based on the suitability values of the chemical elements that affect irrigation water quality. The suitability value approaches 5, the quality of water decreases. Conversely, high desirable drainage water quality has low suitability value. To clarify the raster and to be acceptable the individual values are merged to five classes according to suitability of drainage water for irrigation as shown in ***Table (6)***. [15]

Table (6) Proposed classes and their suitability values of the suitability of drainage water for irrigation

Classes	Suitability value
1	Excellent
1.1 - 2.0	Good
2.1- 3.0	Permissible
3.1 -4.0	Doubtful
4.1 - 5.0	Unsuitable



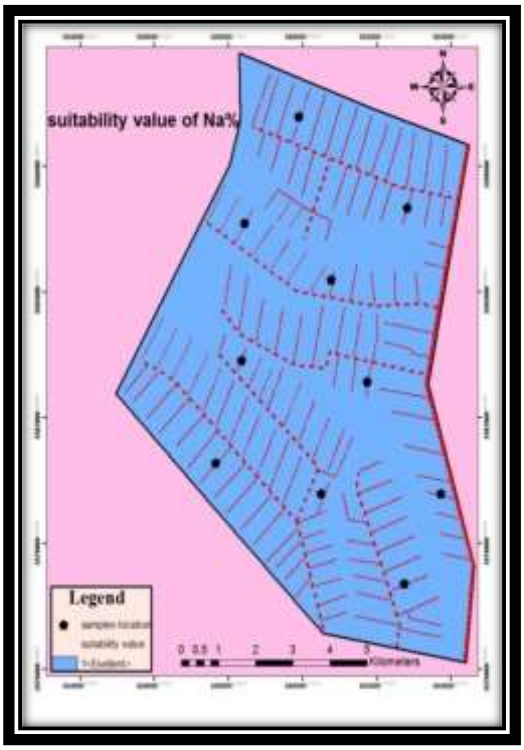
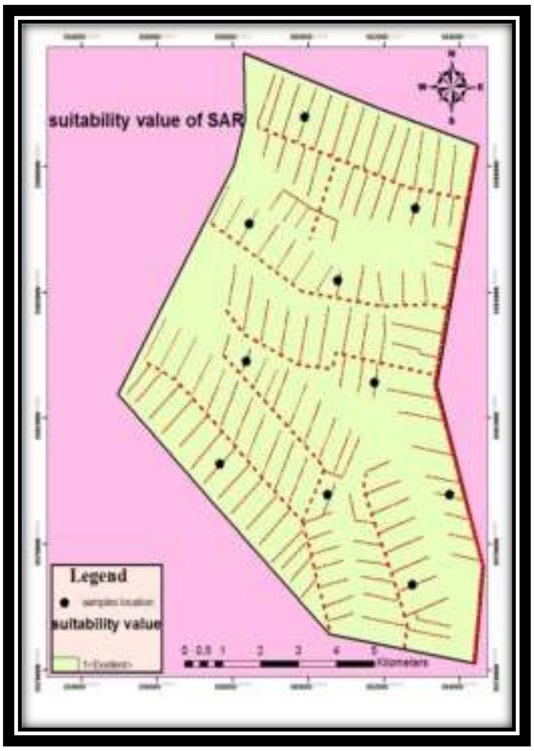


Figure (11) Reclassified suitability of EC

Figure (12) Reclassified suitability of Na%



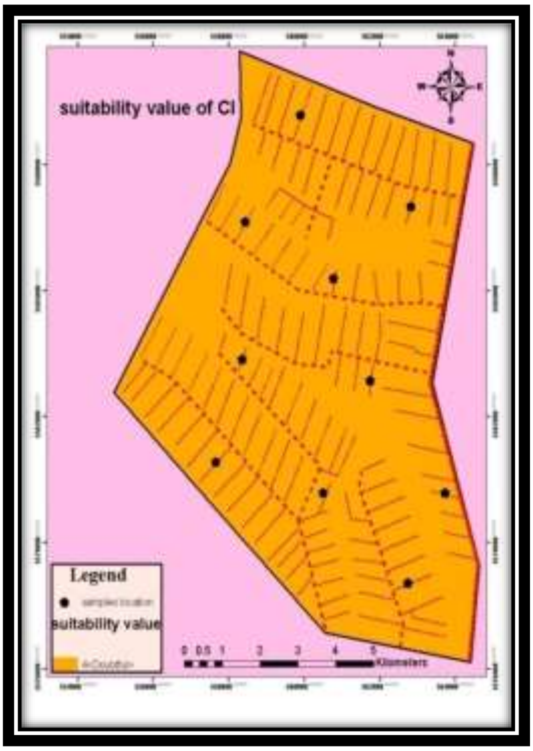


Figure (13) Reclassified suitability of SAR

Figure (14) Reclassified suitability of Cl

6- Results and Discussion

6-1 chemical evaluation

The results of chemical analysis of drainage water of Al-Hussainia main drain are shown in ***Table (7).*** From these results, it can be concluded that there is a salinity problem spatially during summer months where the concentrations are high, while there is no soudicity problem.

Analysis of the results by Aq.Qa software shows that:

1- The internal consistency (e.g. Anion-Cat ion Balance) of the samples was okay .

2-The Residual Sodium Carbonate (RSC) was zero because the bicarbonate concentrations were low.

3- There was a high salinity hazard while there was no sodium hazard.

4- The program determined the water type (e.g., $Ca\text{-}HCO_3$ or $Na\text{-}SO_4$) by finding the predominant inorganic cat ion and anion. The water type was figured on the basis of electrical equivalents (Aq.Qa users guide). In this study, the predominant inorganic cat ion was Ca^{+2} and the predominant inorganic anion was at most Cl^- and sometimes SO_4 .

5-This program also indicate magnesium hazard in all locations in October ,in location 4,5,6 in September and 5,6 in February while there is no magnesium hazard in the other months .

Table (7) average values of six locationsof the tested element during the study period

month / para.	Ca^{+2} Ppm	Mg^{+2} ppm	Na^+ ppm	K^+ ppm	Cl^- ppm	SO_4 ppm	HCO_3 ppm	NO_3 ppm	EC µS/cm	TDS ppm	P^H	TH ppm	Alkalinity	SAR	Na%
Jul.	736.5	164	161	6.63	961	1046	377	17	4456	3620	8.02	2746	138	1.4	12
Aug.	1025	276.4	582.5	5.78	2126	1459.8	391.5	4.8	6996	5954	8.07	7898	165	4.02	25.6
Sep.	672.6	399.9	1257	3.52	2231	2583	482	7	8395	7812.5	8.03	3253	213	10.7	47.5
Oct.	451.5	498.3	752	7.27	1835	1996	214	9.4	6917	5883	8.3	3019	190	6	34.2
Nov.	782	303	744.5	11.53	1843	1924	217	9.4	6935	6072.5	7.6	3198	260	5.7	33.6
Dec.	805	147	175	3.7	1046	1281	264	16.9	4752	3766	7.77	2616	184	1.5	12.9
Jan.	355	142	256	2.62	416	1148	191	3.6	3452	2523	7.5	1466	163	2.77	26.9
Feb.	168	97	79	4.5	152	574.5	247	7.6	1952	1328	7.43	777	141	1.2	17.9
Limits (FAO, 1997)	≤400	≤150	≤920	≤78	≤1065	-	-	-	≤3000	≤2000	6 -8.5	≤500	-	-	-

6-2 Leaching Requirements Calculations

The leaching requirements and mixing calculations results may be summarized as:

1. For wheat crop, the drainage water may be used directly for irrigation without reducing the yield (that's 100% yield potential) at all locations but with leaching fraction of 0.25.
2. For barley crop the drainage water can be used safely in direct irrigation without reducing the yield (100 % yield potential) providing leaching fraction of 0.15

for locations 3,4,and 5 while a leaching fraction of 0.17 should be provided for locations 1 ,2 ,and 6.

3. For corn crop the drainage water is unsuitable for irrigation unless it is mixed with irrigation water to eliminate the salinity hazard .however the mixing ratio is 0.5 for all locations except location 2 where the mixing ratio should be 0.6.

6-3 Evaluation of Drainage Water Quality Using the GIS software

Three-dimensional spatial analyst of the GIS software provide one raster representing the suitability model of drainage water quality for irrigation after evaluations of four rosters of constraint factors. The final raster gives the spatial extensions of the suitability of drainage water for irrigation. From the chemical analysis results of water samples of the study area, it was found that the (EC) value falls within the suitability value of 5, (Na%) value was falls within the suitability value of 1, (SAR) value falls within the suitability value of 1 and (Cl) value falls within the suitability value of 4. The sum of these suitability values is equal to 11. The final model represents the mean of these suitability values on a cell-by-cell basis between input rosters, then the mean value is equal to (11/4=2.75) which fall within the range of (2.1 – 3.0). According to the statistical analysis of these four rosters, the water of the study area can be classified as a water of Permissible irrigation quality. The final model is shown in Figure (15).

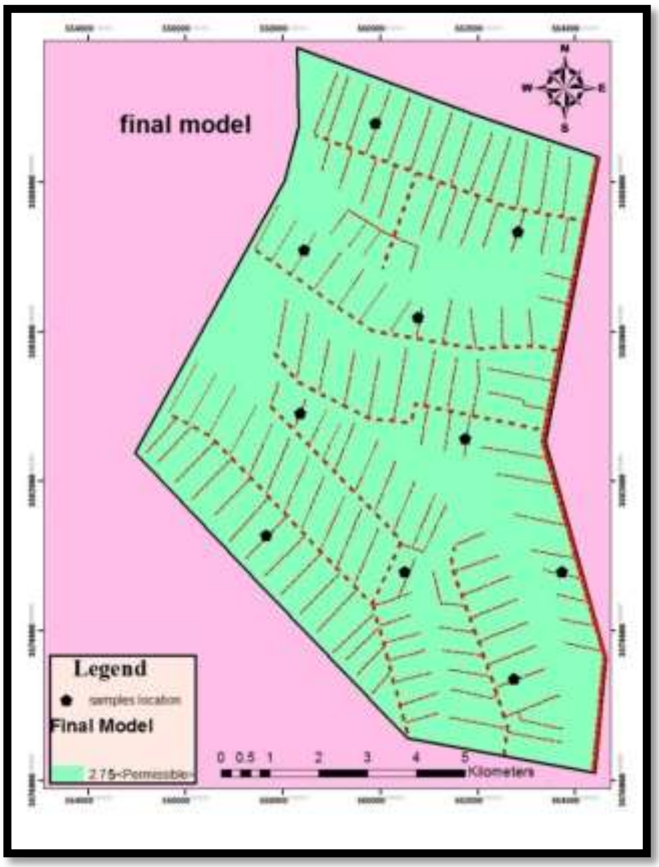


Figure (15) Final Model of the study area

7-Conclusions and Recommendations

7-1 Conclusions

1. There is a salinity problem spatially during summer months where the concentrations are high. While there is no soudicity problem.
2. For wheat crop, the drainage water may be used directly for irrigation without reducing the yield (that's 100% yield potential) from all locations with leaching fraction of 0.25.
3. For barley crop, the drainage water can be used safely in direct irrigation without reducing the yield (100 % yield potential) providing leaching fraction of 0.15 for locations 3,4,and 5 while a leaching fraction of 0.17 should be provided for locations 1, 2, and 6.
4. For corn crop, the drainage water is unsuitable for irrigation unless it is mixed with irrigation water to eliminate the salinity hazard. However the mixing ratio is 0.5 for all locations except location 2 where the mixing ratio needed is 0.6.

7-2 Recommendations

1- More evaluations are required by using the GIS software to investigate the suitability of other water sources for irrigation purposes, such as ground water, drainage water and waste water and Using other models by the GIS software to make evaluation for another reach of Al-Hussainia main drain or another sector of Al-Dalmaj j project or any other drainage in Iraq .

2- Making more evaluations to use other methods of irrigation such as sprinkler or drip irrigation and comparing the results of these methods with these results obtained from surface irrigation.

3- Studying the effect of radiation and toxic ions on crops production.

4- Use the drainage water to irrigate wheat and barley directly with leaching fraction of 0.25 for wheat crop for all locations .while a leaching fraction of 0.15 for locations 3,4, 5 and a leaching fraction of 0.17 for locations 1 ,2 ,and 6 should be provided for barley crop.

5- Growing another crop with less tolerance to salt and irrigate them with blended water.

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