Kufa Journal of Engineering
Vol. 7, No. 1, January, 2016, P.P.67-78
Received 21 June 2015, accepted 8 December 2015

EVALUATION OF SUITABILITY OF DRAINAGE WATER OF AL-HUSSAINIA SECTOR (KUT IRAQ) TO IRRIGATE COTTON CROP

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ABSTRACT

In this study, a specified area of Al-Hussainia sector (which is the middle sector of Al-Dalmaj irrigation project in Kut city/ Iraq) has been selected to be evaluated for its water suitability to irrigate cotton plant. The evaluation include: first Chemical evaluation of drainage water, second Analysis of drainage water by Aq.Qa software, and third computations of Leaching requirements for cotton crop. For the chemical evaluation the most important indicators for the salinity problem considered are (Electrical Conductivity, Total Dissolved Solids, Sodium Adsorption Ratio (SAR) and Sodium Content). The analysis of the hydrochemical results by Aq.Qa program shows that the internal consistency of the samples was acceptable.

It is concluded that in the months July to October most of the measured concentrations of the tested elements were greater than the other four months because in hot weather the evaporation will increase which decrease the quantity of dissolved oxygen in water which cause the increase in concentrations of these elements. However the drainage water of Al-Hussainia sector can be used directly to irrigate cotton without reducing the yield with leaching requirement of 0.18 for location 1, leaching fraction of 0.17 needed for locations 2 and 6, while a leaching fraction of 0.16 should be provided for locations 3 ,4 ,and 5. However there is no need to mix the drainage water with fresh water.

تقييم صلاحية مياه البزل لقطاع الحسينية (كوت-العراق) لري نبات القطن

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الخلاصة

في هذه الدراسة تم اختيار مساحة محددة من قطاع الحسينية(القطاع الوسطي لمشروع الدلمج الاروائي في مدينة الكوت /العراق) لتقييم صلاحية مياهها لري نبات القطن. التقييم تضمن: اولا التقييم الكيميائي لمياه المبزل، ثانيا تحليل مياه البزل بواسطة برنامج تحليل المياه, AQ.QA SOFTWARE وثالثا حساب متطلبات الغسيل لنبات القطن.

بين تحليل النتائج ببرنامج AQ.QA ان التجانس الداخلي للعينات كان مقبولا. تم الاستنتاج ايضا بان مياه المبزل يمكن استخدامها لري نبات القطن بشكل مباشر بدون التاثير على الإنتاجية مع توفير متطلبات غسل مقدارها 0.18 للموقع رقم 1، ومتطلبات غسل 0.17 للمواقع 2و6، في حين ان المواقع 3,4و5 تحتاج متطلبات غسل مقدارها 0.16. ولا توجد حاجة الى خلط مياه البزل بمياه عذبة لري نبات القطن.

1. INTRODUCTION

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 peoples, will live in regions of severe water scarcity. In dry areas where water is scarce it is very important to exploit all available water. The use of drainage water is an important strategy for supplementing water resources. Also reuse helps to avoid environmental problems such as water pollution. Furthermore, reuse may help alleviate drainage disposal problems by reducing the volume of drainage water involved [11].

Many researches have been done around the world about the reuse of waters of marginal quality. Drainage water is one of these waters and can be reused successfully to irrigate some crops [11].

A 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 [7].

The aim of this study is to evaluate the suitability of drainage water to irrigate cotton crop. The case study was a specific area of Al-Dalmaj project/Al- hussainia sector (kut/Iraq). The evaluation program involves the effect of salinity on cotton crop production, computing the leaching requirements and finding what if there is need to mix drainage water with fresh water.

2. PROJECT DESCRIPTION

The study was conducted in Al-Dalmaj project/ Al- hussainia sector (in Kut city/ Iraq). 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 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 t`o11.45. Fig. 1 shows the site plan of Al-Dalmaj project [1].

Fig. 1. Site plan of Al-Dalmaj project [1]

3. METHODS OF USING DRAINAGE WATER

Two methods will be discussed for utilizing Al-Hussainia main drain's saline water to irrigate the cotton crop these methods are cyclic and blending.

3.1. Cyclic

Saline drainage water is used solely for certain crops and only during certain portions of their growing season. The objective of the cyclic method is to minimize soil salinity during salt-sensitive growth stages, or when salt-sensitive crops are grown. With a cyclic method, 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 method 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 [6].

Drainage water can be used to irrigate crops directly using cyclic method, 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 evapotranspiration needs of the crops must pass through the rootzone 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 [14].

The necessary leaching requirement (LR) can be estimated from Fig. 2 for general crop rotations.

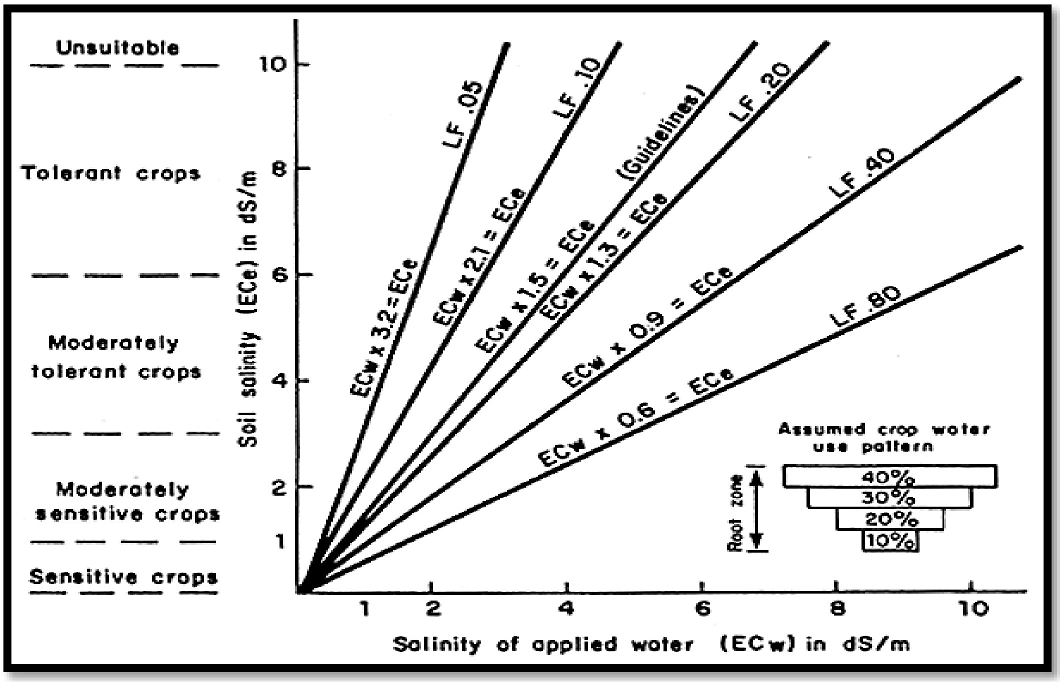


Fig. 2. Effect of applied water salinity (ECw) upon root zone soil salinity (ECe) at various leaching fractions (LF) for 100% yield potential [5]

For more exact estimates for a particular crop, the leaching requirement equation (Eq. 1) should be used:

$$LR = \frac{EC_W}{5(EC_e) - EC_W} \quad (1)$$

Where

LR: Leaching Requierments

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" [12].

3.2. 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 [6].

If there were two water resources the first one is (a) and the second is (b), the quality of the blended water can be found by using equation (2):

$$\begin{pmatrix} concntration \\ of\ the \\ blended\ water \end{pmatrix} = \begin{pmatrix} concentration \\ of \\ water\ (a) \end{pmatrix} \times \begin{pmatrix} proportion \\ of\ water \\ (a) used \end{pmatrix} + \begin{pmatrix} concentration \\ of \\ water\ (b) \end{pmatrix} \times \begin{pmatrix} proportion \\ of\ water \\ (b) used \end{pmatrix} \qquad 2$$

Where the concentration can be expressed as either ECw or ppm but the same units of concentration must be used throughout the equation [5].

The mixing ratio can be found by equation (3):

$$Mixing\ ratio\ =\ Drainage\ water : irrigation\ water \qquad 3$$

In this research the closest fresh water resource to the main drain is Al-Mazzaq cannel. Al-Mazzaq cannel chemical analysis results are typed in Table 1 and these results were taken from water department laboratory.

Table 1. Average results of Al-Mazzaq cannel chemical analysis during the study period [2]

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

4. THE CHEMICAL EVALUATION

The criteria used to evaluate the quality of drainage water for use in agriculture are salinity of irrigation water for salt built up in soils and its adverse effect on plant growth, sodicity for its deleterious effect on soil physical properties**,** 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 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, a mathematical equations and models were applied to evaluate the water quality for its reuse in irrigation in Al-Hussainia sector these equations are:

Sodium Adsorption Ratio is defined by [13]:

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}} \quad 4$$

The Residual Sodium Carbonate equation is [13]:

$$RSC = (CO3\text{-}2 + HCO3\text{-}) – (Ca +2 +Mg+2) \quad 5$$

All concentrations are expressed in (mg/l) [13].

Table 2 shows the classification of irrigation water according to SAR. , Table 3 shows the classification of irrigation water according to Residual Sodium Carbonate.

Table 2. Classification of irrigation water based on SAR values [9]

Level	SAR	Hazard
S1	<10	No harmful effects from sodium.
S2	≥10–<18	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 3. 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 [4]

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 affects 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 [10].

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 Fig. 3.

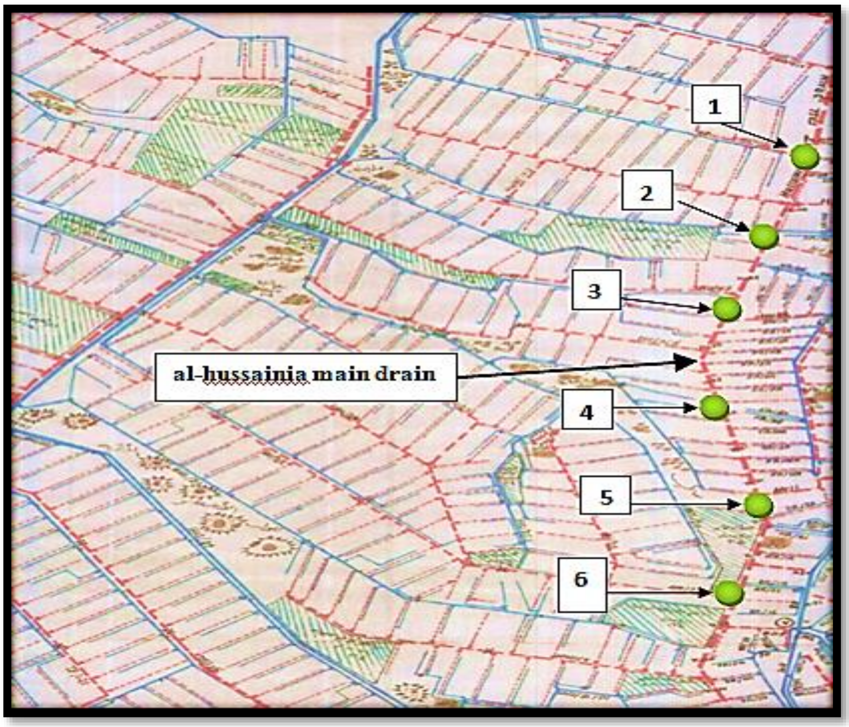
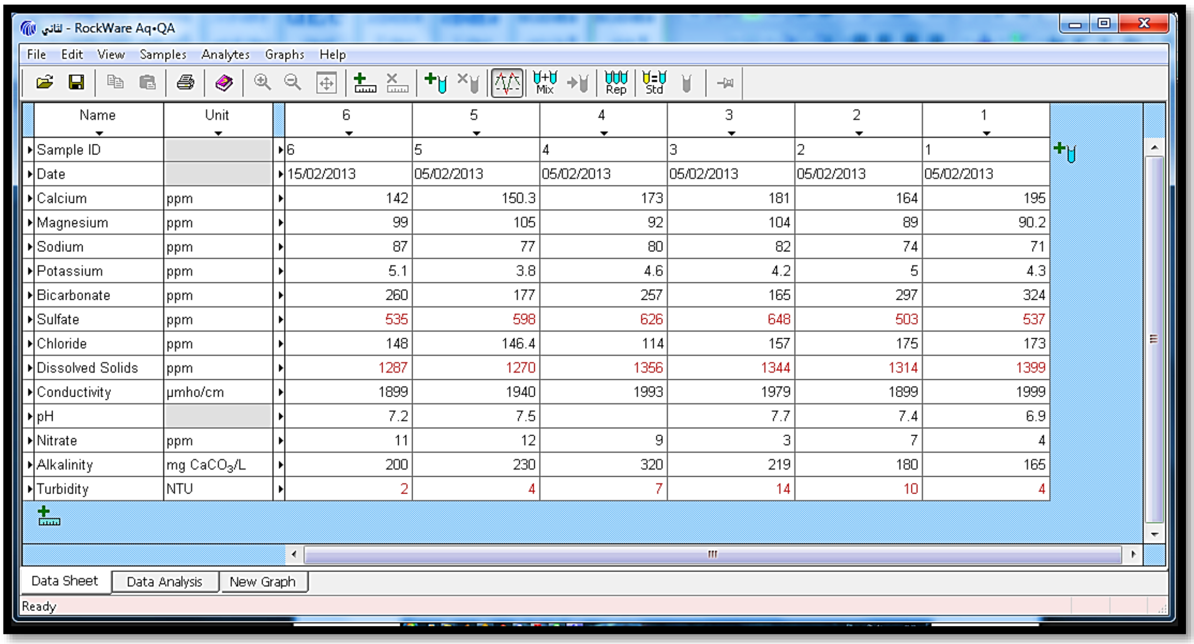


Fig. 3. Samples locations overtaking from Al-Hussainia main drain

To evaluate the quality of drainage water Rockware Aq. Qa [the spreadsheet for water analysis] version1.1.1 [1.1.5.1] was used as shown in Fig. 4.



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	105	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	535	598	626	648	503	537
Chloride	ppm	148	146.4	114	157	175	173
Dissolved Solids	ppm	1287	1270	1356	1344	1314	1399
Conductivity	μmho/cm	1899	1940	1993	1979	1899	1999
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	320	219	180	165
Turbidity	NTU	2	4	7	14	10	4

Fig. 4. Aq. Qa Software window with the data of the six locations entered in February 2012

5. RESULTS AND DISCUSSION

5.1. Chemical evaluation

The results of chemical analysis of drainage water of Al-Hussainia main drain are shown in Table 4**.** From these results it can be concluded that there is a salinity problem especially during summer months where the concentrations are much higher than the limited values, while there is no soudicity problem.

In the months July to October, most of the measured concentrations of the tested elements were greater than the other four months because the hot weather will increase the evaporation which decrease the quantity of dissolved oxygen in water which cause the increase in concentrations of these elements.

Water analysis of the results by Aq.Qa software showed that:

1- The internal consistency (e.g. Anion-Cation Balance) of the samples was within the limits.

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

3- There was 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 cation and anion. The water type was figured on the basis of electrical equivalents (Aq.Qa user's guide). In this study, the predominant inorganic cation 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 4. Average values of six locations of the tested element during the study period [2]

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	pH	TH ppm	Alka linity	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**	**-**	**-**	**-**

5.2. Leaching Requirements Calculations

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

1. The drainage water can be used safely to irrigate cotton crop directly without reducing the yield (100 % yield potential) providing leaching fraction of 0.18 for location 1, leaching fraction of 0.17 needed for locations 2 and 6, while a leaching fraction of 0.16 should be provided for locations 3 ,4 ,and 5.
2. There is no need for mixing drainage water with fresh water to irrigate cotton crop.

Table 5. The Leaching Requirements for two yield potential 100% & 90%

		Location					
Crop		1	2	3	4	5	6
Cotton	LR for100% yield potential	0.18	0.17	0.16	0.16	0.16	0.17
	LR for90% yield potential	0.14	0.13	0.12	0.12	0.12	0.13

For the likelihood prediction of soil water salinity, sodicity and toxicity related problems resulting from irrigation, we can use the method that is presented by Rhoades, et.al, (1992). With this procedure salinity, or solute concentration, is estimated by multiplying the EC (or solute concentration) of the irrigation water by a relative concentration factor, Cf, appropriate to the leaching fraction and depth in the rootzone. These factors are given in Table 7.The assessment of water for irrigation suitability is made based on tolerance of the crop to the predicted levels of salinity (EC), sodicity (SAR) and concentration of toxic ions.

In the following section, this method was applied to drainage water of Al-Dalmaj project/Al-Hussainia sector to assess its suitability for irrigation. The results are plotted in Figs. 5–8. Let's take Fig. 5 for example: in location 1 the leaching requirements of 0.05 and 0.1 are unsuitable for direct irrigation because the salinity will rise above threshold value for cotton crop and so on for the chloride and boron concentrations.

From Fig. 8 it can be conclude that there was no sodicity hazard where all values situated on area of unlikely permeability hazard.

Table 6. Salt, chloride and boron tolerance (threshold) limits for some grain crops [8]

Crop	Tolerated value of EC_e (ds/m)	Slope %	Tolerated value of CL_{SW} ppm	Tolerated value of B_{SW} ppm
Wheat	6	7.1	2100	3
Barley	8	5	2100	3.4
Corn	1.7	12	525	2
cotton	7.7	12	2625	6

Table 7. Relative concentration or electrical conductivity of soil water (saturation paste Extract basis) compared with that of irrigation water (Cf.) [8]

Rootzone intrval	Cf					
	Leaching fraction					
	0.05	0.1	0.2	0.3	0.4	0.5
	Linear average					
Upper quarter	0.65	0.64	0.62	0.60	0.58	0.56
Whole rootzone	2.79	1.88	1.92	1.03	0.87	0.77

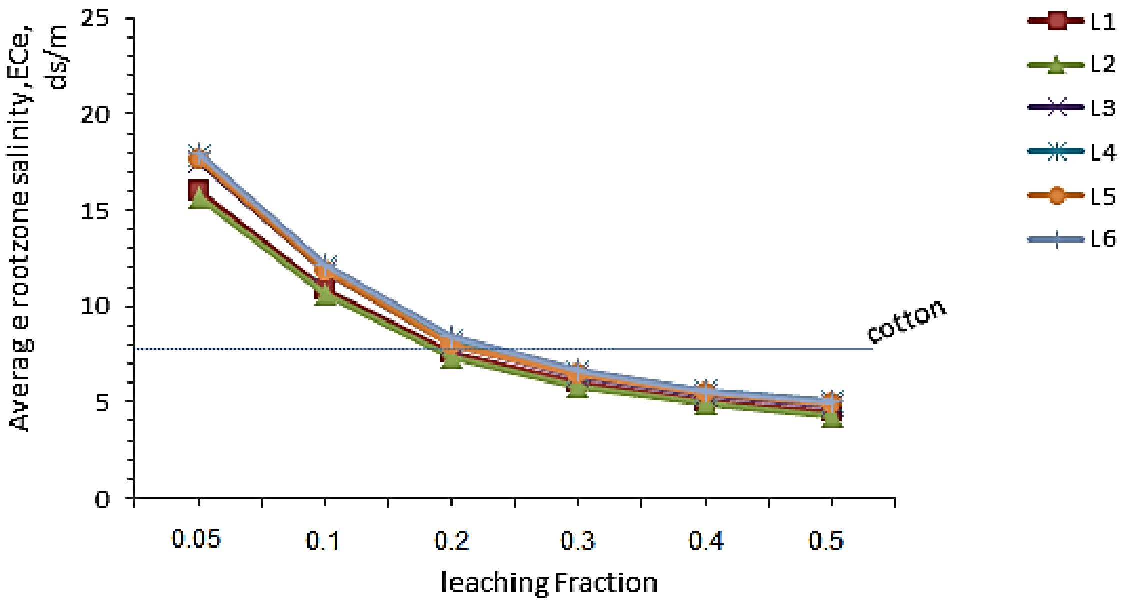


Fig. 5. A Comparison of rootzone salinities produced using drainage waters for irrigation with maximum levels tolerable by representative crops without reducing their yields

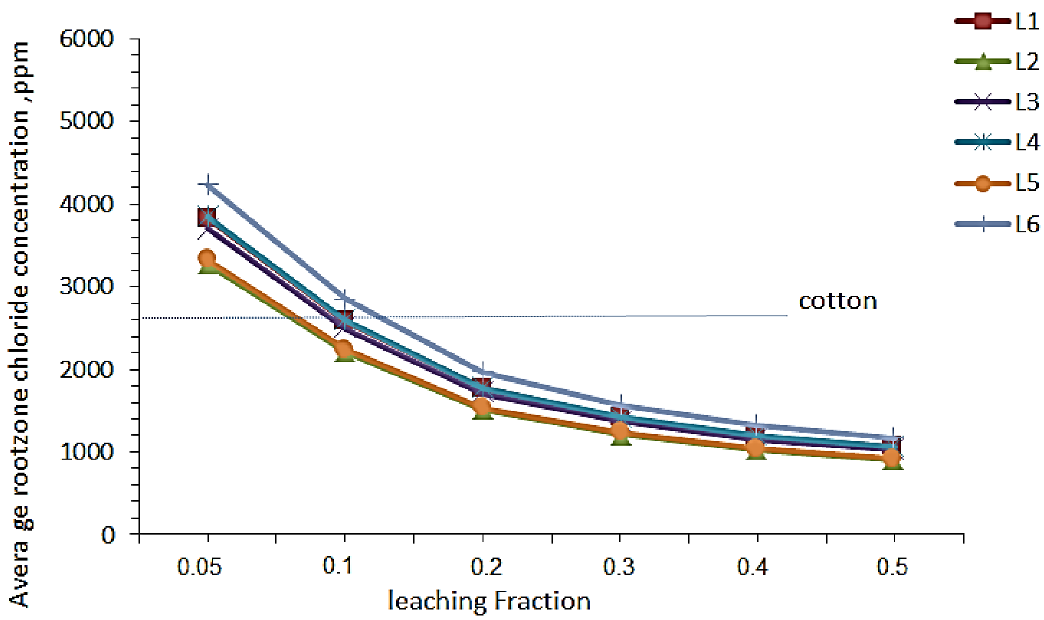


Fig. 6. A Comparison of rootzone chloride concentrations produced using drainage waters for irrigation with maximum concentrations tolerated by representative crops without reducing their yields

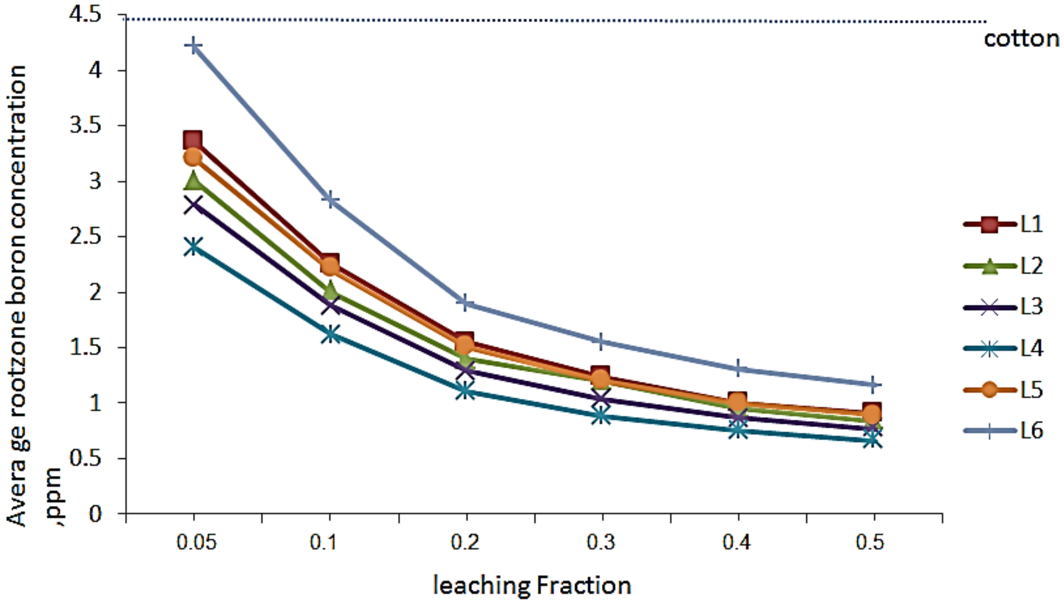


Fig.7 Rootzone boron concentrations produced using drainage water for irrigation

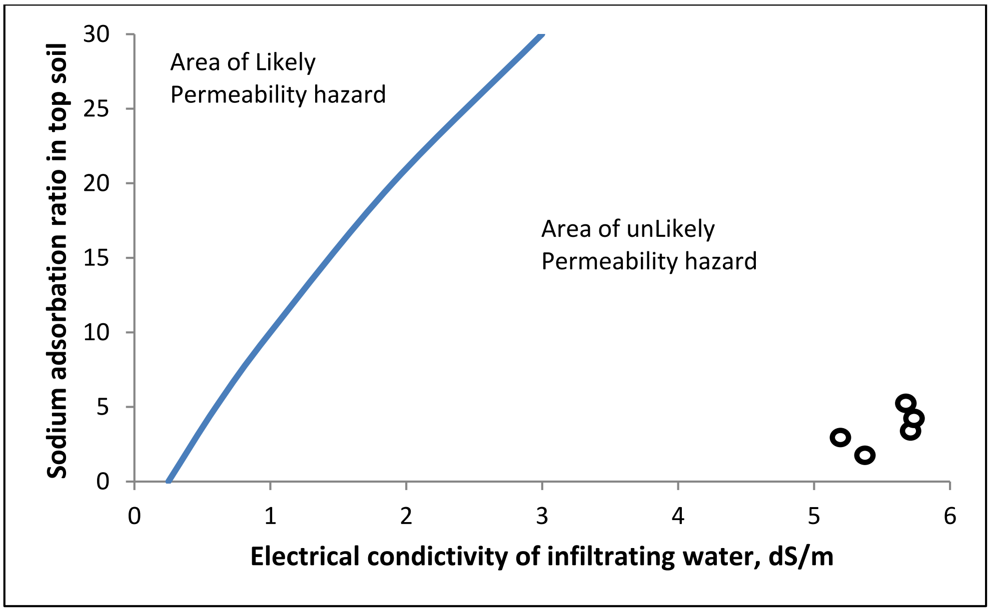


Fig. 8. A Comparison of SAR-EC combinations produced with use of drainage water for irrigation with those associated with adequate and inadequate soil permeability

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

1. There is a salinity problem spatially during summer months where the concentrations are high. While there is no soudicity problem.
2. The drainage water can be used safely to irrigate cotton crop directly without reducing the yield (100 % yield potential) providing leaching fraction of 0.18 for location 1, leaching fraction of 0.17 is needed for locations 2 and 6, while a leaching fraction of 0.16 should be provided for locations 3, 4, and 5.

3. There is no need for mixing drainage water with fresh water to irrigate cotton crop.

6.2. Recommendations

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

1. Assessing the suitability of Al-Hussainia main drain's water to irrigate more crops other than cotton.
2. Growing another crops with less salt tolerance and irrigate them with blended water.

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