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AGRICULTURAL DRAINAGE WATER REUSE OPTIONS , POTENTIAL, COSTS AND GUIDELINES

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INTRODUCTION

The population growth rate and rising living standards are the most water related challenges facing Egypt. The most important challenge is Egypt's expected population growth from 59 million in 1997 till 83 million in 2017, and related water demand for public water supply and economic activities, in particular agriculture. Both challenges have put more stress on both land and water resources. Increased industrial growth together with intensified agriculture also has a direct impact on surface as well as ground water quality.

To satisfy the needs of this growing population Egypt has been engaged in an intensive program of economic development. New towns were built, modern industrial and agricultural projects were introduced, water resources management were adjusted and changed from supply management to demand management policy….etc.

Increasing pressure on available fresh water resources in many areas of the world creates continued interest in the use of marginal quality water for irrigation. The reuse of agricultural drainage water is already practiced on a large scale in several countries. Egypt is one of the leading countries in the reuse of drainage water for irrigation. Annually, Egypt uses 85% of its available fresh water resources in the agricultural sector, a situation that has resulted in a National Policy for the reuse of drainage water. Consequently, since 1988, an area of approximately 1million feddan in the Nile Delta depended on drainage water for irrigation. By the year 2017 it is expected that drainage water would contribute 8 billion cubic meters per year to country water resources. However, increased salinity is expected to limit full utilization of this amount. Intrusion of saline groundwater from the Mediterranean Sea contributes to the increased salinity conditions, in particular in the northern part of the Nile Delta.

The drainage water that flows out of the Delta to the sea represents part of the irrigation water that is in excess of crop evapotranspiration, in addition to canal tail water losses, and water disposed into or collected by the drain throughout its course(seepage from the aquifers. Under reuse practices, some of the drainage water is lifted out of the drains to the irrigation system at certain locations. A portion of this water flows back again to the drainage system either to the same drain or another drain and is conveyed out of the system to the sea.

The combined impact of urbanization and industrial production has created acute environmental problems. The compulsion for economic growth and lack of understanding of the long-term damage potential of pollution has resulted in the manifest deterioration of Egypt's natural resources. The Egyptian government has recently become increasingly aware of the importance of environmental risk management for economic development, health, and quality of life. The challenges facing the country in implementation of a nation wide program to improve the quality of the Egyptian Water Resources for generations to come, are taken seriously into planning consideration.

To protect the water resources environment from over consumption, pollution and rising threats from limited water resources and increased demand a concerted action from the government has to be promoted. The Drainage Water reuse became one of the major elements in water resources planning to increase water availability of different sectors and activities.

Background and Experiences on Drainage Water Reuse

The idea of reuse of drainage water in Egypt is as old as the construction of drainage projects. In the year

1928 the Upper Serw Pumping Station was constructed in the north-eastern part of the Nile Delta to lift water from the Serw drain and blend it with fresh water of Domietta Branch. The apparent reason for this is two-fold:

1. The quality of drainage water was reasonable and its quantity was small when compared with the discharge of Domietta Branch.
2. There was a need for additional supply of water at the tail-end of the system even at that early date.

Since then, mixing of drainage water with fresh water continued to cover the whole delta as well as different orders of irrigation canals.

The number of mixing points in the three parts of the delta (east, middle and west) has reached almost twenty-five stations so far.

In the Upper and Middle Part of country where the cultivated land is formed by a narrow strip running parallel to the River Nile, all drainage water is disposed back to the river. This was carried out early in the sixties when the High Aswan Dam was constructed and the majority of agricultural land in thins region was converted from basin into perennial irrigation.

The above mixing policy is adopted by the Ministry of Water Resources and as a part of its official policy. However, drainage water the spatial distribution of irrigation water in Egypt can never be absolutely even.

The areas at the heads of irrigation canals get more water on the expense of the areas at the tail-ends. Canals getting water at the beginning of the network obtain more discharges than those at the bottom of the system.

The Egyptian farmer, upon feeling that fresh water supply is becoming short, especially during period of peak demand, directly moves his portable pump to the nearest drainage to irrigate his field. This is not done automatically without knowing its consequences. Farmers have some clue about drainage water salinity, they know how tolerant their crop to this water, they use the appropriate management procedure of keeping the soil profile in the root zone always in a wet condition and finally they leach accumulated salts during low demand in winter when the supply is plentiful and the demand is minimal. It is worthwhile mentioning that the crop rotation plays an important role in this respect. If a low water consuming crop is grown in winter (like wheat), it is usually followed by rice, which leaches any accumulated salts. If a deep-rooted crop is grown in summer (like cotton) it is usually followed by berseem which is a highly water consuming crop. This succession system of cropping appears to be the main reason for having a state of equilibrium in most of the delta lands and it explains the constant and rather low salinities of these lands.

Another experiences gained from drainage water reuse when it was used to reclaim new areas in northern of the Nile Delta, where since 1948 Edko and Burolus lakes started to dried out to create new agricultural lands. These areas completed its drying up by year 1950, land reclamation. Authority received the areas in 1955 to continue reclamation operation. The main source of water used to reclaime these area was drainage water of Edko main drain in Western Nile Delta and Gharbia main drain in Middle Delta. The Drainage Research Institute was the lead institute to study the impact of such water quality on land reclamations process. The evaluation took place in pilot areas of about 7700 feddans laying to the east of lake Edko and of about 28,000 feddans falls to the north of the delta at the south east of lake Borollos. The results of these studies proves the possibility of using drainage water for land reclamation and leaching as long as salt concentration in water sources is less than that of the soil, provided that a complete, good, and sound drainage system should be available. Additional finding was the possibility of using drainage water for irrigation with good farm management and organization, which means application of suitable irrigation methods together with carrying out leaching operation from time to time.

The drainage system in Egypt is only a juvenile when compared with the irrigation system. Although some drainage projects were executed as early as 1920, yet, it was only late in the sixties when intensive drainage projects started. Since then, measurements on drainage water were carried out in order to quantify the factors that affect irrigation-drainage relationship and to finally get an insight into the conveyance, application and overall efficiencies of the irrigation system. Preliminary investigations revealed that vast quantities of drainage water of reasonable quality flow to the Mediterranean Sea and the coastal lakes every year. This fact strengthened the desire to conduct accurate measurements aiming at either the reduction of these flows by improving irrigation efficiencies or the reuse of good quality drainage water for irrigation purposes or both.

The present prolonged drought in South and East Africa, which started to affect water resources in Egypt, changed this desire into a real must.

The Drainage Research Institute with the continuous help and assistance of Dutch government took the lead in establishing a network of measuring stations on the key points of main drains in the Nile Dleta and Fayoum in the late seventies and continued till almost year 2000 and then extended by Canadian government. In less than ten years, a semi-automated network was kept functioning, measurements on regular basis are made, rating curves for each location were furnished and regularly updated, measuring equipment installed and periodically maintained and a smooth flow of data from the field until the publication of yearbook including all details was accomplished. The measurement programme enables obtaining information about quantity and quality of drainage water at the present time. Future estimates can only be known by prediction. Mathematical models are the appropriate tools used in this respect.

The SIWARE model (Simulation of Water Management in Arab Republic of Egypt) was formulated in a fashion that follows mathematically the flow of water from the source (Delta Barrages) down into the conveyance network till the lowest order to the distributary canals from which farmers abstract water to irrigate their fields. On-farm irrigation, evapotranspiration, drainage water generation and redistribution of salts in the soil profile is then simulated to get the change in quantity and quality of drainage water when any expected changes in water management policies, cropping patterns, water duties,... etc. take place. Thanks for the Dutch continuous help and Assistance for DRI in this field.

Currently; with the support of the Canadian AID for development, the Drainage Research Institute extend the work done by the African development bank (DWIP) studies on the impact of drainage water irrigation on the soil characteristics and crop yield production. The study include different new dimension such as the impact on socio economic conditions, health aspects , development of indicators to measure the awareness of the new graduated students, investors by the environmental status in the area. The study also involve the private sectors in the development and management process by introducing the soil and water extension services; and farmer and grower participation on farm management.

Generally; Fig (1) shows the current on going reclamation project in both Eastern and Western Nile Delta which depend on agriculture drainage water, which evaluated as in total of 823,000 feddans(330,000 hectares)

All the above experiences gained in the field of drainage water reuse withrespect to management, operation and prediction were used in the current studies to fulfill the following objectives:

Crop yield responses to farm management;
Potentiality of Drainage Water Reuse ;
Farmer Participation and Water User Associations;
Costs / Benefits of Drainage Water use;
Application of Drainage Water Reuse Guidelines.

Drainage Water Reuse Options

Description of the Experimental Field

Mariut experimental field station is located just off the Cairo/Alexandria desert road, about 35 km south of Alexandria. The site is situated within a traditional farming area that is composed of small farms near the tail end of main irrigation canal. Farmers in this area use the traditional Egyptian farming methods including surface irrigation in furrows and basins. The irrigated land is provided by subsurface drainage systems, which was installed in May 1999. The site is irrigated directly from the intake of distributory canal taking its water from Abu-Khalifa Canal which already use mixed supplied water from drainage water by Mariut Pumping Station with fresh water taking from Nubaria main canal.

The experimental field suffers from problems related to irrigation practices. These problems are:

Water shortage due to the over-irrigation by farmers at the head of the canal (the site is at the tail-end of the distributory canal)
Increased salinity of the irrigation water.
Increased ground water salinity and increased $CaCO_3$ contents

General water quality of the irrigation canal ranges between 2-4 mmhos/cm, depending on the mixed quantity of drainage water with the fresh water. The irrigation and drainage water mixing is carried out, based on water levels in irrigation canals and not on preset mixing ratios.

The nature of the soil is calcareous soil with predominantly light composition.

The growing seasons in the region are two main growing seasons per year. The winter season which runs from about October to May and the summer season which runs from April-May to October. The selected crops during the experiment period were maize and sunflower for summer season.

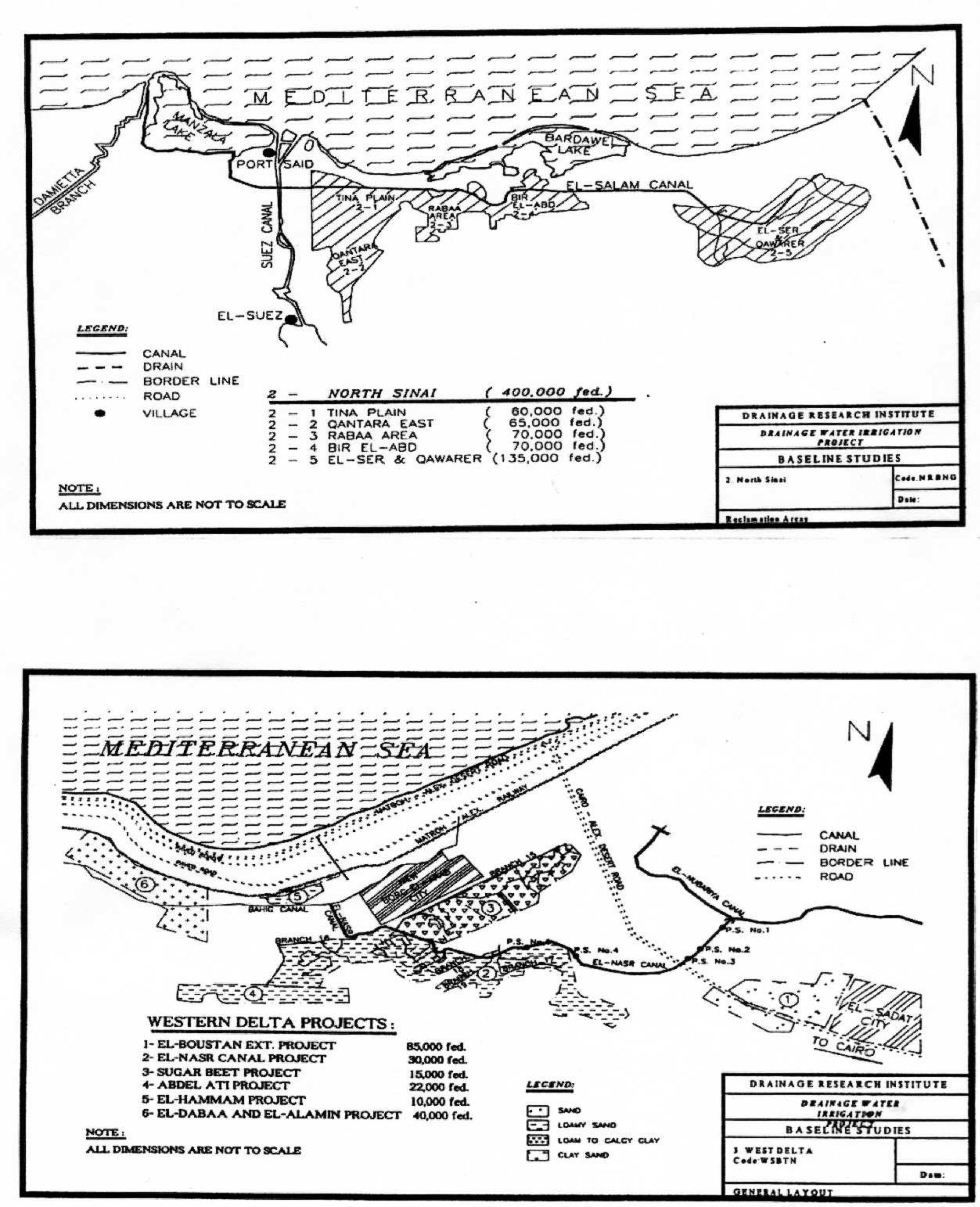

Fig. 1. New reclamation project using agriculture drainage water

Experimental Design

The field study was carried out in a 4.2 ha. field with a sand-silty loam soil. The area was provided with line field irrigation canal with constructed gated pipe to each field plot. See Fig.(2) below:

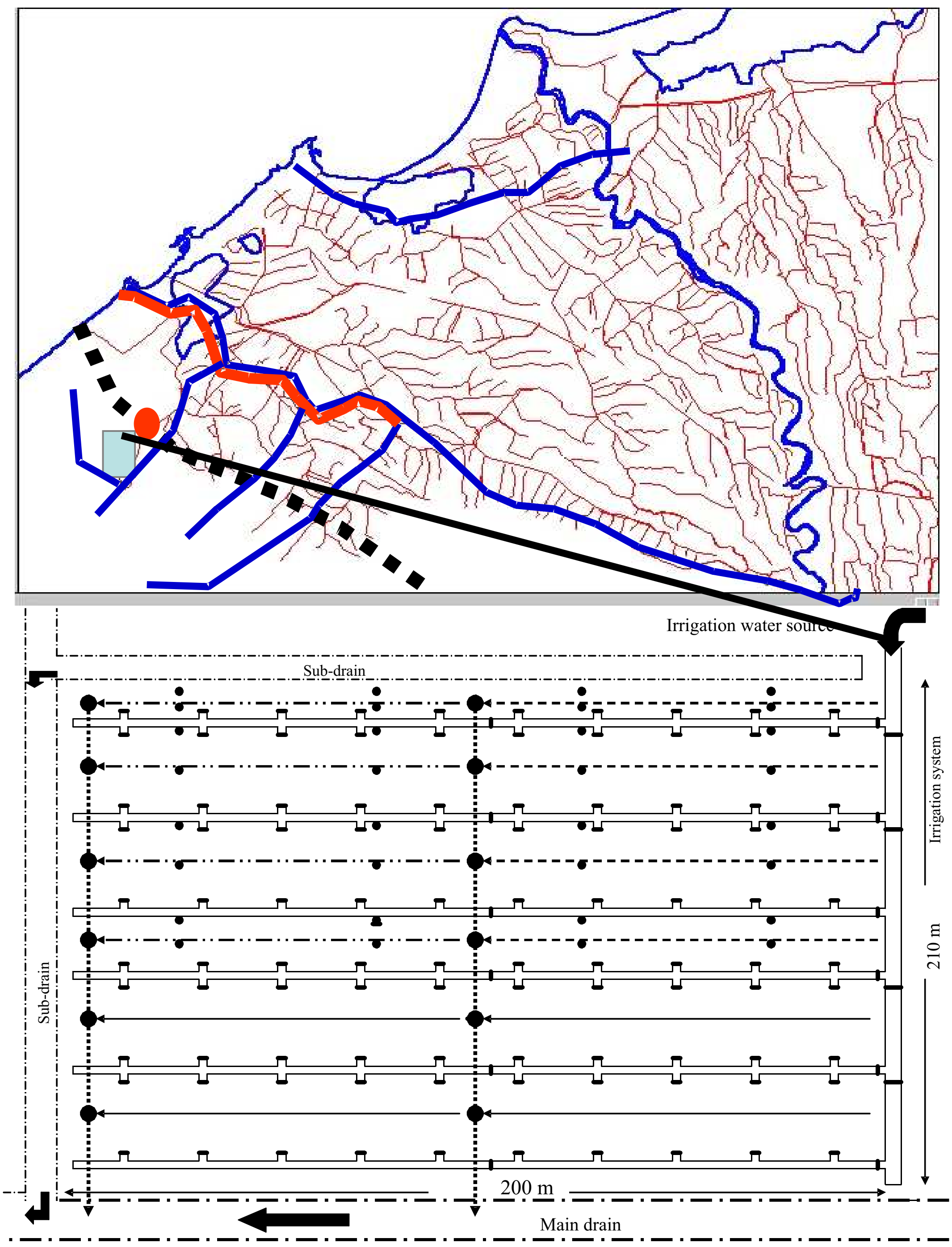

Fig. 2. Layout of the irrigation and drainage system in the experimental fields

The treatment strategies tested in the area are:

- Fresh water (FW) strategy where the sole use of canal water supplied to 50% of the experimental field. This strategy is considered as the overall control treatment

- Drainage water (DW) strategy where the sole use of the drainage water supplied from main drain serving the area to the other 50% of the experimental farm.

This strategy represents the conventional method for utilizing drainage water in areas suffering from water shortage of irrigation water supplies.

The irrigated crops within each part of the experimental field are: maize and sunflower used in the area as animal fodder and oil extraction respectively.

Soil characteristics

The experimental field is located in Western Delta, specifically in the new old land that have been reclaimed and extended since early 1960. The area is considered to have sandy soil type with very low soil moisture content and with active internal drainage in the presence of quite a high percentage of calcium carbonate $CaCO_3$, which has some impact on soil characteristics.

A soil profile of six tensiometers were installed in the study area. Installation depth were .15, .30, .40, .80, 1.2, and 1.6 m. theses were monitored daily in the growing season . the tensiometers measured total and matric potential of water in the soil profile at different depths. The total potential values were used to indicate direction of water movement in the soil and the matric potential values were used to give a measure of soil wetness. The samples were collected in three stages during the summer seasons: initial, middle and at the end of the season to be able to follow up salinity status during irrigation. Results of the analyzed samples showed the following :

soil texture analysis showed that about 52% of the samples collected from the area were loam soil texture and about 11% are silty loam and 9% sandy loan soil texture respectively. In general, the tested soil type could be considered as loamy soil.

The $CaCO_3$ percentage was as high as 53%, and the overall average of $CaCO_3$ content about 48%, even the minimum value of $CaCO_3$ is considered as very high where it reached 19%. Therefore, the experimental field soil is considered as loamy calcareous soil.

Soil moisture release curves were prepared in situ for the study site using coinciding soil moisture and potential measurements at five depths in the soil profile. These curves indicate how much water will be lost from the soil profile for a given decrease in potential caused by, for example, root water abstraction or gravity drainage. As the pressure potential in soil decreases, the largest pores empty of water first, followed by successively smaller pores.

As the soil dried beyond this it became increasingly difficult to extract water. Thus, the soil is characterized by large pores which hold most water. It is very permeable and dries out rapidly following water application. As expected for a sandy soil, it drains quickly and has a small water holding capacity.

The moisture content for a given potential value became higher with depth. This implies there are textural differences with depth. The soil's water holding capacity increased with depth, implying a higher percentage of small pores. This is borne out to some extent by the textural analysis which indicated increasing proportions of fine soil particles with depth.

Field capacity matric potential vary between -50 and -200 cmH_2O. This equates to a moisture content between 18% and 22% by volume. This is low moisture content for field capacity and highlights the poor water holding capacity of this soil.

The soil chemical analysis of soluble salts along the season (initial, middle and end of the season) showed the following results.

- Saturated soil paste of the samples was almost around 40-50% because of its sand and loam content.
- Soil salinity in soil extracts was ranged between 2-4 mmhos/cm except at the end of the seasons where it was observed at higher values (5-6 mmhos/cm).

- Dominant salts are Na, Cl and Ca or Mg SO_4. Na concentration was found to be 15-30 meq/l, while Ca and Mg ranged between 4-6 and 4-10 meq/l respectively. The chloride and sulphate ions ranged between 16-30 and 5-15 meq/l respectively.

Soil salinity analysis during different stages of growing season were done and results are presented in Table 1. It was obliviously that an increase in soil salinity from 4 to 7 mmhos/cm within canal water irrigation treatment, and also it could be observed an increase of soil salinity to about 9 mmhos/cm within the drainage water irrigation treatment.

Salinity distribution along the soil profile showed no trends and no significant changes. Sometimes there is salinity build up on the top soil layer rather than the lower layers, which may be explained by the fact that salts are moving up from lower layers to the top soil layer during the dry period between irrigation intervals and during the non-irrigation period at the end of the season.

Due to irrigation with low water quality (in both irrigation water treatments) salinity build-up is expected. This observation may be considered for the next irrigation season by applying proper leaching fraction. Also this salinity build-up is not harmful in soil characteristics when soil texture is loamy (which is considered as light soil) and allow fast removal of salts to the drainage system in the next sequence irrigation. Problems of such leaching fraction should be determined according to irrigation water quality and soil salinity.

Table 1. Soil Salinity status in dS/m under different irrigation conditions

	Fresh (Mixed Nile and drainage) Water Treatment			**Pure drainage Water Treatment**		
	initial-sum	**Mid-sum**	**end-sum**	**initial-sum**	**Mid-sum**	**end-sum**
Sun Flower	4.65	5.45	5.62	19.85	26.50	53.00
	3.45	5.95	5.43	20.65	64.50	37.65
	3.60	5.10	6.76	20.40	21.30	35.25
	5.10	5.60	7.13	19.75	17.80	27.90
Maiz	3.30	5.40	5.92	7.25	5.745	9.17
	5.35	5.55	7.28	3.4	5.915	6.905
	4.45	5.30	6.19	3.4	5.805	7.405
	3.30	4.75	8.43	3.65	5.985	6.855

Irrigation

Irrigation water supply and its salinity are considered as major parameters in on-farm management where they contribute to sustainable water and salt balance in the experimental farm, especially when salt content of such supplied water is classified as "salty water". Generally, it was observed that farmers are using extensive water to overcome salinity. Results of irrigation measurement (quantity , quality and average salt load) are given in Table 2 ,3, 4, 5 where one can find the following:

Irrigation water quantity given for each gift expressed as depth in cm. the overall quantity of irrigation water for each treatment also given as depth and m3/feddans.

Maize crop receives about 4486m^3 of canal irrigation water treatment and 4473m^3 drainage water per feddan ; while in the Nile Delta areas such crop receives about 3230 m^3/feddan, of canal good water quality. It was noticed that maize crop received 8 gifts while the normal field in Nile Delta receives from 6 - 7 irrigation gifts during the growing season.

The irrigation process adds about 10.14 and 10.5 tons of salt to the irrigated fields, while the normal field irrigated with good water quality of 300 ppm adds about 0.96 tons of salt

Sunflower crop receives 6 irrigation gifts. The quantity delivered through irrigation water is estimated as 2956m^3 with canal and 3007m^3 with drainage water m^3/feddan/season. These quantities add about 7.10 and 7.4 tons of salt respectively to both treatments. While in comparisons with irrigated sunflowers in Nile Delta with good water quality it receives about 3000 m^3/feddan/season through about 5-6 irrigation gifts.

Table 2. Irrigation Water depth (in Cm) Given under different Treatment

Date	Treatment			
	Fresh Water		Drainage water	
	Maize	Sunflower	Maize	Sunflower
08/06/01	11.75	13.38	12.00	14.12
19/06/01	14.09	7.54	12.20	8.47
27/06/01	12.57	11.39	13.23	9.59
12/07/01	14.83	14.16	14.27	13.71
29/07/01	13.20	11.94	12.57	13.23
16/08/01	14.18	11.99	14.04	12.48
02/09/01	13.83		14.42	
16/09/01	12.36		13.78	
Total quantities in (Cm depth)	106.82	70.40	106.52	71.60

Table 3. Irrigation Water Salinity (dS/m) Given under different Treatment

Date	Treatment			
	Fresh Water		Drainage water	
	Maize	Sunflower	Maize	Sunflower
08/06/01	4.57	5.10	4.38	4.44
19/06/01	4.32	4.25	4.60	4.46
27/06/01	3.74	3.72	3.87	4.11
12/07/01	2.81	2.88	3.55	3.25
29/07/01	3.35	3.40	3.34	3.48
16/08/01	3.30	3.30	3.38	3.49
02/09/01	3.12		3.21	
16/09/01	3.22		3.22	

Table 4. Quantity of Salts(in Tons) added with supplied irrigation water

Date	Treatment			
	Fresh Water		Drainage water	
	Maize	Sunflower	Maize	Sunflower
08/06/01	1.44	1.83	1.41	1.68
19/06/01	1.64	0.86	1.51	1.02
27/06/01	1.26	1.14	1.38	1.06
12/07/01	1.12	1.10	1.36	1.20
29/07/01	1.19	1.09	1.13	1.24
16/08/01	1.26	1.06	1.27	1.17
02/09/01	1.16	0.00	1.24	0.00
16/09/01	1.07	0.00	1.19	0.00
Total Salts added in Tons	10.14	7.09	10.50	7.36

Table 5. Quantity of Salts added with irrigation under different Irrigation Treatment Compared with Nile Water Irrigation (400ppm)

item	Treatment			
	Fresh Water		**Drainage water**	
	Maize	Sunflower	Maize	Sunflower
Within The Study Area				
Supplied Water m3/feddan	4486.23	2956.75	4473.64	3007.33
Added Salts Ton/feddan	10.14	7.09	10.50	7.36
Within Delta Areas				
Supplied Water m3/feddan	3230	3230	3230	3230
Added Salts Ton/feddan	0.969	0.969	0.969	0.969
Ratio				
Supplied Water	1.39	0.92	1.39	0.93
Added Salts	10.47	7.31	10.83	7.60

Notice : 1 feddan = 4200 m2

Figure 3 shows the quantity of irrigation water and salts added to different treatments supporting these findings. Analyzing the above mentioned results the following information could be concluded :

There is no clear difference between quality of canal water and drainage water used in the pilot farm. This may be explained based on the fact that such areas are located at the tail end of irrigation distribution systems and are subject to supplementary irrigation water by drainage system crossing the canal to increase the irrigation canal water levels. This increases salinity of irrigation water supplied by such canals, and contributes to the increase of salts quantity added to the agricultural fields in these areas.

Irrigation water supplied to these areas are 40% more if it is compared to areas in the Nile Delta. Therefore, it could be considered that the leaching fraction used in such areas is about 0.4 to overcome salinity of the supplied irrigation water. This fraction is considered a very large fraction which adds more salts to the irrigated areas and adds additional costs for farm irrigation. Therefore the leaching fraction of such areas should be determined according to its irrigation water quality and soil characteristics

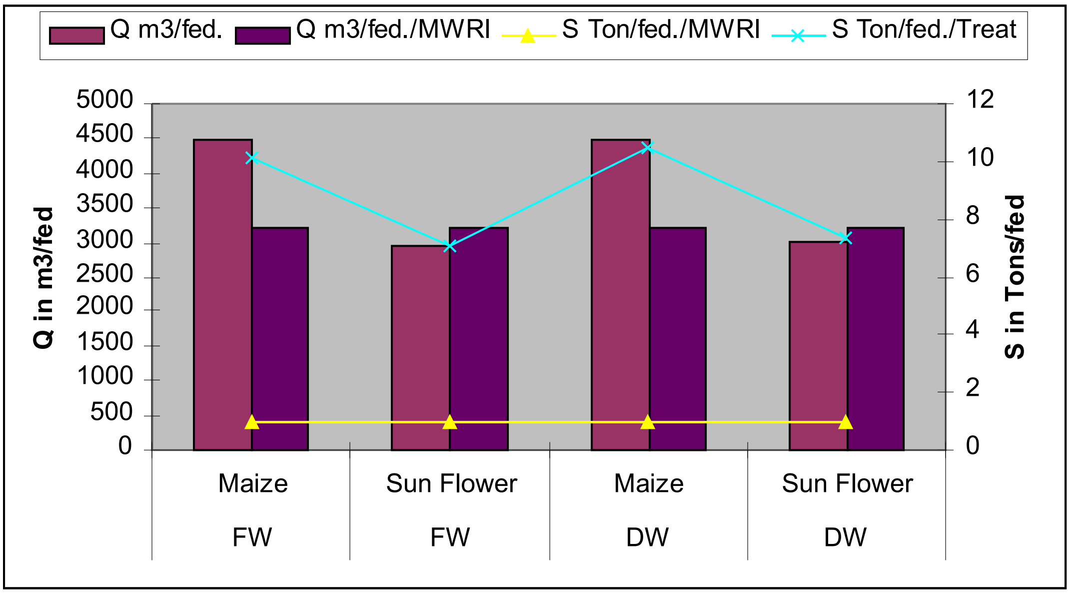

Fig 3. Total irrigation quantity and Salts added to irrigated crops.

Drainage

Drainage conditions play an important role in providing plants with suitable environment with respect to salinity stress conditions, water logging and air exchange process. These conditions contribute to crop production. Therefore, drainage conditions were evaluated by monitoring the water table, drainage discharges and water quality to estimate quantities of salt removed from cultivated fields. Results of drainage performance showed that groundwater table was subject of fluctuation in midway between drains as a result of irrigation practices. This fluctuation was mainly due to the natural drainage condition rather than the functionality of the laterals in some areas where the drains did not show much flow. This may be due to over designed drainage system in some areas and under design drainage system in another. It was very important to report that a very small significant difference was observed in drainage outflow quantities from different irrigation treatments under different crops. This observation leads to the following results:

Total volume of drainage water flow under irrigation with canal water and drainage water for maize were 454 and 504 m^3/season. These quantities remove only 1.43 and 1.86 tons of salt respectively. Thus low drainage outflow quantities; referred to unsuitable discharge measurement under submerged conditions and also no measurements of downward flow through seepage from agricultural land to the aquifer. It is not logic to find that low values of drainage outflow from irrigated areas receive such quantities of irrigation water unless the natural drainage is very active. In other words, the drainage rate in the experimental fields is found to be as 10.1% and 7.7% of the total supplied irrigation water, which seems to be very low values.

Similar results were observed in irrigation of sunflower crop where the drainage quantities estimated were 376 m^3 for canal water irrigation and 334 m^3 for drainage water irrigation respectively. The quantity of salt removed were about 1.2 and 1.23 ton/salt, which seem very low. The volume of drainage water outflow represented about 12.7 and 11.5% respectively of the irrigation water supply.

From the above results the following conclusion can be made as :

The drainage system serving the experimental field is not functioning very well due to under design of collectors and maybe blockages of the system. The system should be redesigned and properly maintained

It is very important to develop methods to measure and/or estimate natural drainage in such areas

Most salts removed naturally or artificially should be properly estimated. The total volume of drainage water in areas with good drainage conditions range between 35 - 40% of the total irrigation gifts which includes all field drains and irrigation system losses through cracks and ground surface.

Evapotranspiration

The actual evapotranspiration or consumptive use depends mainly on soil physical condition as well as on the maximum evaporative demand and crop water use characteristics and finally on crop properties. Based on the available climatic data, the empirical relationship “Modified Pennman“ were selected to estimate the maximum evaporative demand. According to crop development (as crop height and fraction of soil cover) the environmental factor (Kc) were applied to estimate the actual Evapotranspiration. The estimated results showed the following :

The overall quantities of water used by crops and lost from soil surface are estimated as 1607 and 1497 m3/season for maize and sunflower crops

These values are found to be less than what was expected where it represents about 36% and 50% of the total irrigation water supplied to the field, while the estimated crop Evapotranspiration for such crops (maize) within the Delta area is estimated as 2560 m^3/season which represents about 79%; and about 1690 m^3/season for sunflower crops which represent about 60% of the supplied irrigation water in the Delta agricultural lands

These estimated values can be explained based on the reduction factor used in the calculation is much lower than one unit; in addition these kc values are an average of values of crops in different areas within climatic region.

The differences in estimation of crop Evapotranspiration depend only on the kc values, which consider the environmental conditions affecting crop growth. The average values used in these estimates are 0.68 and 0.65 for maize and sunflower respectively; and the monthly distribution of the kc values is as follows

	June	July	August	September
Maize	0.59	0.92	0.76	0.44
Sunflower	0.51	0.68	0.76	0.56

The reduction factor for crop environment should be evaluated for each crop within each test area using direct method based on “on-farm management”. In addition , from the current study, the kc value seems to be more than a unit, because it does not give the large evapotranspiration values that are found under arid conditions.

Although the irrigated crops receives much irrigation water, more than similar crops grown in the Delta areas, by about 40%; the crop water use in this experimental field is less than for crops grown in the Delta. This may be due to high salinity that can affect the crop water extraction and dominate the stress condition. This fact may denote that the plants can sustain soil moisture conditions for a much longer period than the salinity stress condition.

Overall field water and salt balance

To achieve favorite water and salt balance, the following assumptions could be made:

All salt are highly soluble and do not precipitate,

The amount of salts supplied by rainfall is negligible,

The amounts of salt supplied by fertilizers are exported by crops are negligible

No seepage, long term equilibrium between the root zone and the subsoil ($C_g = C_r$)

All irrigation water mixes with the soil water in the root zone at field capacity ($C_{fc} = C_r$)

In the case of salt equilibrium (i.e., without a long-term change in salt content), the changes in salt content in the root zone can be estimated as

$$Z` \quad \frac{IC_i \quad \frac{R^x Z`_1}{W_{fc}}}{1 \quad \frac{R^x}{2W_{fc}}} \qquad 1$$

Where:

Z` = Change in salt quantity in the rootzone (meq/m2) = Z`2 - Z`1

Z`2 = Salt quantity in the rootzone at the end of the period (mq/m2)

Z`1 = Salt quantity in the rootzone at the beginning of the period (meq/m2)

I = Applied Irrigation Water gift (mm)

Rx = Percolation below rootzone as subsurface drainage (mm)

Ci Salt concentration in supplied irrigation water (meq/l)

Wfc The amount of soil water at field capacity in the rootzone expressed in mm or l/m2 can be determined from: where Volumetric soil water content (%) and D Depth of the rootzone (mm)

Cfc The salt concentration At field capacity of the soil water in the rootzone it is determined as

The above mentioned Equation named as the salt storage equation. If the initial salt content of the root zone, Z`1, is known (e.g., from soil sampling), the Z`can be calculate directly. This equation can then be used to predict the Stalinization or the desalinisation processes of soils under the influence of irrigation water quantity and quality. If, however, one are interested in finding the seasonal deviations from the long-tem equilibrium soil salt content, Z` will not be known, and the only condition is that the sum of the quantities Z` should be zero over a long period. This approach has been used to describe the water and salt balance status after each irrigation event in the study area. The results of average salinity of the root zone are shown in table 6. The results can show the following :

Differences between initial salt load at the beginning of the season and the final one at the end of the season are (+610) and (+532) for fresh water irrigation and drainage water irrigation respectively which may indicate salinity buildup in both treatments. This is due to increased salt contents in the supplied water. The Corresponding soil salinity in extract showed an increase from 3.78 to 4.39 dS/m for fresh water irrigation treatment while it showed the same trend in drainage water treatment where the salinity increased from 3.63 to 4.24 dS/m.

Insignificant differences between measured and calculated average soil salinity in both initial and final soil salinity where within the fresh water irrigation these values were 2.68 and 3.63 dS/m for initial status (difference is 0.94dS/m), and 4.43 and 4.24 dS/m for the final status. On the other hand and for the drainage water treatment the initial soil salinity was 3.03 and 3.78 dS/m for the measured and simulated one respectively while for the final status these values were 5.47 and 4.43 dS/m
Seasonal input water and salts during the growing season evaluated as 1048 mm and 1045 mm which are equivalent to about 4486 m3/feddan for both treatment and the corresponding added salts found as 10.4 tons. On the other hands the average seasonal drainage water and salts removals under different treatment showed about 450 and 504 m3/feddan for fresh and drainage water irrigation, with corresponding salts removal of 1.19 and 1.86 ton of salts respectively. This indicates that salinity buildup in both treatments is the dominant processes in the reuse strategies.
The same conclusion could be drawn when comparing the salt concentration in initial and final soil analysis for samples taken along the soil profile representing the different locations within each treatment.

Table 6. Field Water and Salt Balance For Drainage Water Reuse Area

(in Equlibrium State)
Fresh Water Treatment

Part 1 : Basic Information

Water at Field Capacity %	0.4
Studied Root Zoon Depth (m)	0.6
Water at Field Capacity (mm)	240
Relation Between ECe and ECfc	0.5
average ECe in Root Zone(dS/m)	4
Capillary rise contribution (mm)	0

Land Use : S u m m e r C r o p s (Maize + Sunflower)

Simulation Period			total (mm)	Jun	Jul	Aug	Sep
E	(mm)		395	75	135	110	75
P	(mm)		0	0	0	0	0
E-P	(mm)		395	75	135	110	75
ECi	(dS/m)		0	4.3	3.11	3.3	3.17
(E-P)*ECi	(mm.dS/m			322.5	419.85	363	237.75
Part 2 : Distribution of irrigation water with maximum percolation in summer							
deficit			-83				
I	(mm)		1020.1	**353.6**	270.65	133.95	261.9
Delta W	(mm)		0	83	0	0	0
R*	(mm)		625	196	136	24	187
Zi1	(E.C*mm)		**1416**	***1416***	1676	1594	1863
Delta Z1	(E.C*mm)			260	-82	270	-447
Zf1	(E.C*mm)			1676	1594	1863	**1417**
E.Ce	(dS/m)	simulated		**4.74**	**4.50**	**5.26**	**4.00**
		measured		3.76			6.52

continued

Part 1 : Basic Information

Water at Field Capacity %	0.4
Studied Root Zoon Depth (m)	0.6
Water at Field Capacity (mm)	240
Relation Between ECe and ECfc	0.5
average ECe in Root Zone(dS/m)	4
Capillary rise contribution (mm)	0

Land Use : S u m m e r C r o p s (Maize + Sunflower)

Simulation Period		total (mm)	Jun	Jul	Aug	Sep
E	(mm)	395	75	135	110	75
P	(mm)	0	0	0	0	0
E-P	(mm)	395	75	135	110	75
ECi	(dS/m)	0	4.31	3.43	3.44	3.17
(E-P)*ECi	(mm.dS/m		323.25	463.05	378.4	237.75

Part 2 : Distribution of irrigation water with maximum percolation in summer

deficit		-83				
I	(mm)	1031.5	**348**	268.9	132.6	282
Delta W	(mm)	0	83	0	0	0
R*	(mm)	625	190	134	23	207

Zi1	(E.C*mm)	**1416**	***1416***	1676	1594	1863
Delta Z1	(E.C*mm)		260	-82	270	-447
Zf1	(E.C*mm)		1676	1594	1863	**1417**

E.Ce	(dS/m)	simulated	**4.74**	**4.50**	**5.26**	**4.00**
		measured	4.54			8.21

Cost-Benefits of Low Water Quality Irrigation

Based on the available data collected from the experimental farm dealt with on production capital costs and operational costs of the irrigation system; The cost and benefits of crop production irrigated with low water quality can presented as follows :

- **Cost of Crop Production :**

Table 7 shows that in case of Maize crop fresh irrigation water; the total variable costs estimated as 796.88 LE/Feddan which represent 61.45% of the total production costs. The total physical input represent 46.3% and the machinery costs is about 28,24%. The total labor cost represent 25,47% of the total variable costs. While in case of Drainage water irrigation reuse, the total variable costs is evaluated as 914.7 LE feddan which represent 64.66^ of the total production costs. The physical input represented 47.29%; the machinery costs is estimated as 29.51%, finally the labor cost was estimated as 23.2% of the total variable costs.

On another hand and in case of sunflower crops; fresh irrigation water; the total variable costs were estimated as 543.3 LE/feddan which represent about 49.7% of the total production costs. The total inputs of physical costs represented by 51.04%; then the total machinery costs of about 32.03% and the total labor cost estimated as 16.93% of total variable costs.

The Drainage water irrigation for the same crop showed the total variable costs were estimated as 677.65 LE/feddan which represent 55.20% of the total production costs. In addition the percentage of the total physical inputs, labor costs and the machinery costs were 51.98%, 16.061 and 31.96% respectively out of the total variable costs.

Table 7. Costs of crop production under different Irrigation conditions in L.E)

Crop	Item	Fresh Water	Drainage
Maize	Production Inputs	368.88	432.6
	Labor Cost	203	212.1
	Machinery Cost	225	270.0
	Variable Cost	796.88	914.7
	*Total Production Costs	1296.88	1414.7
Sunflower	Production Inputs	277.3	352.25
	Labor Costs	92.0	108.8
	Machinery Cost	174	216.6
	Variable Costs	543.3	766.6
	* Total Production Costs	1093.29	1227.6

Total Production Costs = Total variable Costs + Land rent value

Relatively importance laborer works for irrigation:

To be able to analyze the costs of irrigation process under different conditions Table 8 showed the following:

In case of Maize crops, the fresh irrigation treatment showed that labor work costs about 48,6 LE/feddan which represent about 23,94% of the total labour force used and bout 6.1% of the total variable costs.

It also showed that the total machinery costs used for irrigation is about 68.1 LE feddan which represent about 30,27% of the total machinery work used in the Farm, and about 8.55% of the total variable costs.

The total cost of irrigation then evaluated as 116.7 LE/feddan which used in maize farm production, this represent about 428 LE/feddan and about 14.64% of the total variable costs.

In case of maize crop irrigated with drainage water; the labor work used for irrigation estimated as 57 LE/feddan which represent about 26,9 % of total labor work used in the farm and about 6,23% of the total variable costs. The machinery work used in irrigation were estimated as 84.15 LE/feddan which represent about 31.16% of the total machinery works in production process; and of about 9,20% of the total variable costs.

The total costs of irrigation processes in this case were estimated as 141.15 LE/feddan which represent about 29.28% of the total costs of labor and machinery works used in the farm which evaluated as 482.1 LE/Fed and represented by 15.43% of the total variable costs.

In case of sunflower crop irrigated with freshwater: the costs of labor work used for irrigation process; were estimated as 17 LE/Feddan which represent about 18.48% of the total labor costs in the production processes, and about 3.13% of the total variable costs. The machinery costs used for irrigation processes were estimated as 42.75 LE/feddan which represent 24.57% of the total machinery costs used in the farm and about 7.87% of the total variable costs.

The total costs of all kind of works in irrigation processes were evaluated as 59.75 LE/feddan; which represent about 22.46% of the total labor and machinery costs which evaluated as 2.66 LE/feddan and about of 11% of the total variable costs.

In case of sunflower irrigated with drainage water: The total labor used for irrigation processes were estimated as 25.4 LE/feddan which represent about 23.35% of the total work costs and it represent about 2.75% of the variable costs. The machinery costs (used in irrigation processes) were estimated as 56.34 LE which represent 26.01% of the total machinery work in the farm, and also represent about 8.31% of the total variable costs. The total costs of all kind of work used for irrigation were estimated as 81.74 LE/feddan which represent 25.12% of all kind of work in the farm which evaluated as 325,4 LE/feddan which also represent about 12,00% of the total variable costs.

Table 8. Evaluation of Irrigation costs under different irrigation conditions.

Crop	Irrigation Farm Activities	Fresh Irrigation			Drainage Irrigation		
		LE	%	$\%^2$	LE	%	$\%^2$
Maize	Labour Work	48.6	23.9	6.1	57	26.9	6.2
	Machinary Work	68.1	30.3	8.5	84.1	31.1	4.3
	Total	116.7	27.3	14.6	141.	29.3	15.4
Sunflower	Labour Work	17.0	18.48	3.13	25.4	23.3	3.75
	Machinary Work	42.7	24.57	7.87	56.3	26.0	8.3
	Total	59.7	22.46	10.9	81.7	25.2	12.1

Net Return Value

Within the current contexts, the net return value of irrigated crops with different water quality; will be presented the following economic indicators:

- Value of the overall production which calculated by multiplication of the marketable production times average cost at the farm gate.
- The total marginal production which estimated by subtracting the total variable costs from the overall productions costs.
- The net return value which estimated as the overall production costs after subtracting the total production costs (variable and fixed costs).

These economical indicators of the current study are shown in table (9) of which the following facts and information can be concluded:

In case of maize crop; The fresh water irrigation gave 1807.95, 1011.07 and 511.07 LE/feddan of the above mentioned economical indicators respectively; while the drainage water irrigation gave 1609.9, 695.2 and 195.2 LE/fed resp.

In case of sunflower crop; The fresh water irrigation gave 1647.3, 1104, 544.01 LE/fed while the drainage water irrigation gave 1425, 747.35 and 197.3 LE/fed for the same economic indicator respectively.

Table 9. Economical Indicators for Irrigated crops with different water quality:

Crop	Water Resource	Overall Production Value L.E	Marginal Production L.E	Net Return L.E
Maize	Freshwater	1807.95	1011.07	511.04
	Drainage Water	1609.90	695.20	195.20
Sunflower	Freshwater	1647.3	1104.0	554.01
	Drainage water	1425.0	747.35	197.35

Drainage water potentiality

The first requirement for implementing the drainage water reuse policy on an environmentally sound basis is to have the necessary tools which provide information about the temporal and spatial distribution of drainage water. The drainage Research Institute (DRI) has established a monitoring network consisting of more than 192 sites for measuring the flow and water quality parameters. These monitoring sites are located along the main a branch drains and it is in full operation since 1984. These measuring sites were selected at different drainage pumping stations and at strategic sites along the open drains. Annual data is supplied and reported in a Yearbook published and distributed by DRI to all concerned authorities and decision makers. Based on results of this activity running at DRI one can conclude the potentiality of drainage water reuse in the Nile Delta Table 10. It is obvious that most drainage water is officially reused through state-constructed pump stations and is of salinity less than 1500 ppm. It is pumped into the irrigation canals and mixed with canal water. The salinity of the mixture is often kept below 1000 ppm, which is a conservative level.

Table 10. Drainage water reuse for irrigation and its salinity ranges mm3/year

Salinity class	**East**	**Middle**	**West**	**Total**
640 – 960	365	671	384	1420
960 - 1280	960	96	292	1348
1280 – 1600	-	-	-	-
1600 – 1920	-	-	-	
1920 -2240	53	-	-	53
>2240	-	-	-	-
Total Average	1378	767	676	2821

The drainage water flowing to the sea still includes about 241million m^3/year with salinity less than 1500 ppm Table 11. Mostly, these quantities are allocated to new land reclamation projects under construction such as El Salam Canal and El Umum Drain Projects. It is expected that the total drainage water reused after implementation of these projects will be about 8.0 billion m^3/year. The allocation of drainage water for further reuse depends not only on its quantity and quality but also on the time and place it is found in addition to the lifting head and corresponding energy required. (Abu Zeid and Abdel Dayem 1991).

Table 11. Drainage water flowing to the sea and its quality class

Salinity class	**East**	**Middle**	**West**	**Total**
960 – 1280	-	-	-	-
1280 – 1600	2411	-	-	2411
1600 – 1920	1813	-	-	1813
1920 -2240	-	1611	-	1611
>2240	193	3017	1170	4380
Total Average	4417	4628	1170	10215

Limitations and threats facing drainage reuse strategies

Drainage water or more specifically drain water (which is collected in the drains) is a mixture of a number of water resources. These resources are:

Surface runoff due to poor land leveling
Agriculture surface and subsurface field drainage
Tail-ends and spillways of irrigation canals connected to open drains
Upward seepage Water collected by drainage systems.
Sea water intrusion to the drains connected to the sea
Seepage from highly elevated water bodies
Possible disposal of domestic seepage or industrial wastewater treated or partially treated or untreated

With this collection of different types of water(s) one expects to have several kinds of pollutants in drainage water: excessive salts, nutrient (P, N), pesticides, herbicides, insecticides, heavy metals, toxic elements, etc. Even if the concentration of these pollutants is small, the accumulation with time will certainly cause harm.

Having stated that drain water is a collection of the above named water(s), it is clear that part of this water, especially surface runoff and tail-end losses can be kept to a minimum in the operation of the irrigation system and improvement of farm management. Doing this will certainly reduce the drainage water availability in the network on one hand, and on the lifting of drainage water to the irrigation canals on the other.

Another limitation of reuse of drainage water in irrigation is that this drainage water is not always available and found in a favorable location. The quantity of drainage water is at its maximum quantity near the tail-end of the system where canal water is at its minimum quantity and the available lands to be irrigated are also scarce.

Finally, not every crop can be irrigated with this water. If sensitive crops are irrigated with unsuitable water, production is significantly affected.

The strategy of drainage water reuse in Egypt was based on one fact which is

"No alternative but to plan for the use, reuse and recycling of each drop of available water"

and to minimize any adverse effects of reusing the drainage water in irrigation purposes. Therefore, the following measures were taken:

- Mixing fresh water with drainage water on the lower scale of secondary drains and canalsrather than the scale of main canals and drains. This helps in the selection of better quality water and the lower lifting head.
- Improved on-farm water management by mixing fresh water during germination, early stages of growth and for leaching, then drainage water or mixed water can be used during other stages
- Use of drainage water only for fiber crops (cotton, flax, timber trees, flowers, etc.)
- Reducing the use of chemical fertilizers, pesticides to the maximum possible extent.

The above-mentioned measures can only be taken and implemented if the present and future statuses of drainage water are known. In addition the impacts of the drainage water reuse are adequately predicted. Therefore, the drainage water reuse strategies were formulated based on:

- Production of the impacts on soil salinity and crop yield using water management simulation models, both for short and long term
- Improvement of the on-farm water and soil management to minimize the adverse effect of salt accumulation using updated drainage water reuse guidelines

Drainage Water Reuse Guidelines

One major objective of the Drainage Water Irrigation Project (DWIP) has been to develop guidelines for the safe and sustainable reuse of drainage water for irrigated crop production in the Nile Delta. One of major objectives of the current study is to apply these guidelines. Such guidelines are intended to help minimize long term degradation of crop productivity and soils in the Nile Delta primarily due to salinity, to preserve environmental values, and to promote social and economic wellbeing of the farmers involved in the use of drainage water

The application of these guidelines intended to:

- Minimizing long term degradation of crops and soils;
- Preserving environmental values and public health; and
- Ensuring the social and economic wellbeing of the farmers

The developed gridlines include three major groups: the agricultural, environmental and socio-economic guidelines. The environmental guidelines include standards for pollutants which should be observed in order to prevent or avoid adverse effects on the crops and their productivity. Likewise, the socio-economic guidelines recognize adverse impacts on crop productivity that may result from the introduction of drainage water for irrigation and the potential loss of farmers' income that may result there from. The current study will focus only on the agricultural guidelines and its application.

Agricultural Guidelines for drainage Water Re-use:

The agricultural guidelines presented her enable the user to rate salinity hazard factors and suggest irrigation and crop management practices to overcome such hazards. They form a decision support system in reuse of drainage water for irrigation. The guidelines are intended for use on currently cultivated lands as well as on new lands being brought into production by reclamation. They are meant to be applied to a specific crop or to a crop rotation, that are to be irrigated with a water of known quality under particular soil salinity and hydrologic conditions. The guidelines are presented in the form of three matrices or tables, each applicable to crops with a specific level of tolerance for salt. They enable the user to evaluate the potential hazards of drainage water reuse for irrigation. These matrices are classified based on the crop tolerant to salinity and defined as:

Matrix for salt tolerant crops (cotton and wheat)
Matrix for moderately salt tolerant crops (maize and rice)
Matrix for salt sensitive crops (faba beans and berseem)

The footnotes provided at the bottom of each matrix give directions to the user as to the determination of the appropriate indices. The technical nature of these footnotes is the reason for limiting the use of the matrix to trained persons. The matrices are designed to identify the relative potential for crop yield reduction and soil salinization when using one of four different types of irrigation water.

Fresh water (F, Canal and Nile Water)
Drain water (D, Drainage water generated from fields normally irrigated);
Mixed water (M, Canal water that has been mixed with drain water);
Groundwater (GW, stress/deficit irrigation)

For a specific crop or crop in a rotation and knowing the type of water to be used (vertical column on the left), the matrix identifies conditions that are known to be associated with yield reductions in saline and/or sodic soils facilitates the identification of factors that can lead to the development of saline and/or sodic soil conditions.

The three winter crops (wheat, berseem and faba beans) and the three summer crops (cotton, maize and rice) which are included in the three matrices are grown on some two-thirds of the 7.5 million feddan cultivated in the Delta. The guidelines are applicable to other crops with comparable tolerance to salt.

Three major effects were considered in the organization of each matrix.

The direct impact of irrigation water quality on crop yield reduction via irrigation water salinity and sodicity hazard
Irrigation water management as regards meeting the consumptive use and leaching needs of the crop; soil quality. This last factor rates the potential of the soil to remain a suitable medium for plant growth in regards to soil salinity and sodicity

These three effects are listed at the top of each table, as headings of the three main columns. The effects are subdivided into sub factors across the top of each matrix, for which categorical criteria levels are set for each crop/irrigation water combination. The criteria within each matrix become more restrictive as crop salt tolerance decreases (from top to bottom of a table, and from Table 12 -1 to Table 12 -3), or as irrigation water salinity increases i.e. fresh to mixed to drainage water , from top to bottom for each crop. The criteria levels were set based on general principles of crop production in saline and sodic soils. They were then modified based on results of the monitoring data collected by the DWIP project where appropriate. The sequences of evaluation of the action to be taken are based on questions to be answered as it is shown in Fig 4 and as the following example which started from question 6 as below :

List the following values required to answer Question 7:	
a. Productivity Cutoff ECiw (also called threshold)…………………	______ ______
b. Productivity Cutoff SARiw……………………………………...	______ ______
c. Irrigated Water Quantity (for the cropping season) allocated per the Department of Irrigation (m^3/fed) …………………………..	______ ______
d. Water Table Depth:……………………………………………...	______ ______
e. Groundwater Salinity ECgw………………………………………	______ ______

f.	Depth to restrictive layer: ……………………………………….	_______
g.	Sodium Adsorption Ration of the soil SAR: ………………………	_______
h.	Establish the ECe (soil electrical conductivity, indicative of its salinity) at planting time for the crop to be grown. Obtain this data from laboratory testing on soil samples. Or, use the ECiw of the previous crop (this is based on the assumption that steady state has occurred during the previous growing season, in which case ECe = ECiw). Alternately, calculate the ECe from the irrigation water salinity ECiw by using the formula: $ECe = 1.839 + 0.813\ ECiw \quad (1)$ Both ECe and ECiw are expressed in dS/m. The formula (1) results from a correlation between soil salinity at the end of an irrigation season and water salinity as observed in some monitoring sites in Egypt. Enter ECe…………………	_______
Evaluate the six sub factors in the appropriate matrix on the basis of the values listed in what have been mentioned above:		
1.	Is the ECiw (measured irrigation water electrical conductivity), indicative of its salinity > cutoff (threshold) value? (see sub factor 1 in matrix)	**Y or N**
2.	Is SARiw > cutoff value? (see subfactor 2 in matrix) Note that knowledge of the water's SARiw (Sodium-adsorption ratio of the irrigation water, which expresses the relative activity of sodium ions in exchange reactions with the soil, is derived by application of a formula to the measured concentrations in the water of Sodium, Calcium and Magnesium ions expressed in meq/l of the respective ions) requires sampling and laboratory testing.	**Y or N**
3.	Is irrigation water quantity **not** sufficient? (see subfactor 3 in matrix). Note that a Y answer means that irrigation water quantity is not sufficient. The appropriate leaching fraction LF is determined from Figure 5 by entering the average root zone soil salinity ECe and the irrigation water salinity ECiw. Adding this leaching fraction to the appropriate crop water requirement, one obtains the total water requirement, which is compared to the irrigation water quantity to be provided to farm to answer the question "is irrigation water not sufficient?". Other accepted methods are available for estimating leaching requirements (see, for example, the procedure outlined in section 623.0205 – Leaching requirements for salinity control pages 2-98 to 2-123 of Chapter 2 of the S.C.S. National Engineering Handbook, Sept. 1993, US Department of Agriculture). Note that if ECe obtained from Figure 5 is greater than ECiw, the value of ECiw should be used for ECe.	**Y or N**
4.	Is there a potential for soil salinization due to either water table depth, water table salinity, restricting soil layer of insufficient leaching fraction (LF) ? (see subfactor 4 in matrix)	**Y or N**
5.	Is there a potential for soil dispersion and related permeability reduction? (see subfactor 5 in matrix) The sodium adsorption ratio of the soil, measured or estimated, is entered on Figure 6 in ordinate, and the irrigation water salinity (ECiw) is entered in abscissa. The potential for dispersion (reduced infiltration rate) is indicated if the point falls above the demarcation line on Figure 6. the answer would then be Y.if it falls below, the answer would be N.	**Y or N**
6.	Is ECe at planting (or at harvest of the previous crop in the rotation) greater than productivity cutoff (crop threshold) ECiw (the productivity cutoff or threshold, is the point at which crop yield begins to decline as salinity increases)? (see subfactor 6 in the matrix)	**Y or N**

Determine matrix overall rating for the crop: If no factor is rated positive (no Y answer in the above), then matrix overall rating for current crop = **SLIGHT which** no special management practices as regards soil salinization need be considered. If one factor is rated positive (one Y answer in the above), then matrix overall rating for current crop = **MODERATE which** consider practice or practices to minimize adverse impact from matrix factor rated positive to prevent yield reductions for current crop or short-term soil degradation. If two or more factors are rated positive (two or more Y answers), then matrix overall rating for current crop = **SEVERE which** require change(s) in practice or practices to prevent significant yield reductions for current crop or soil	

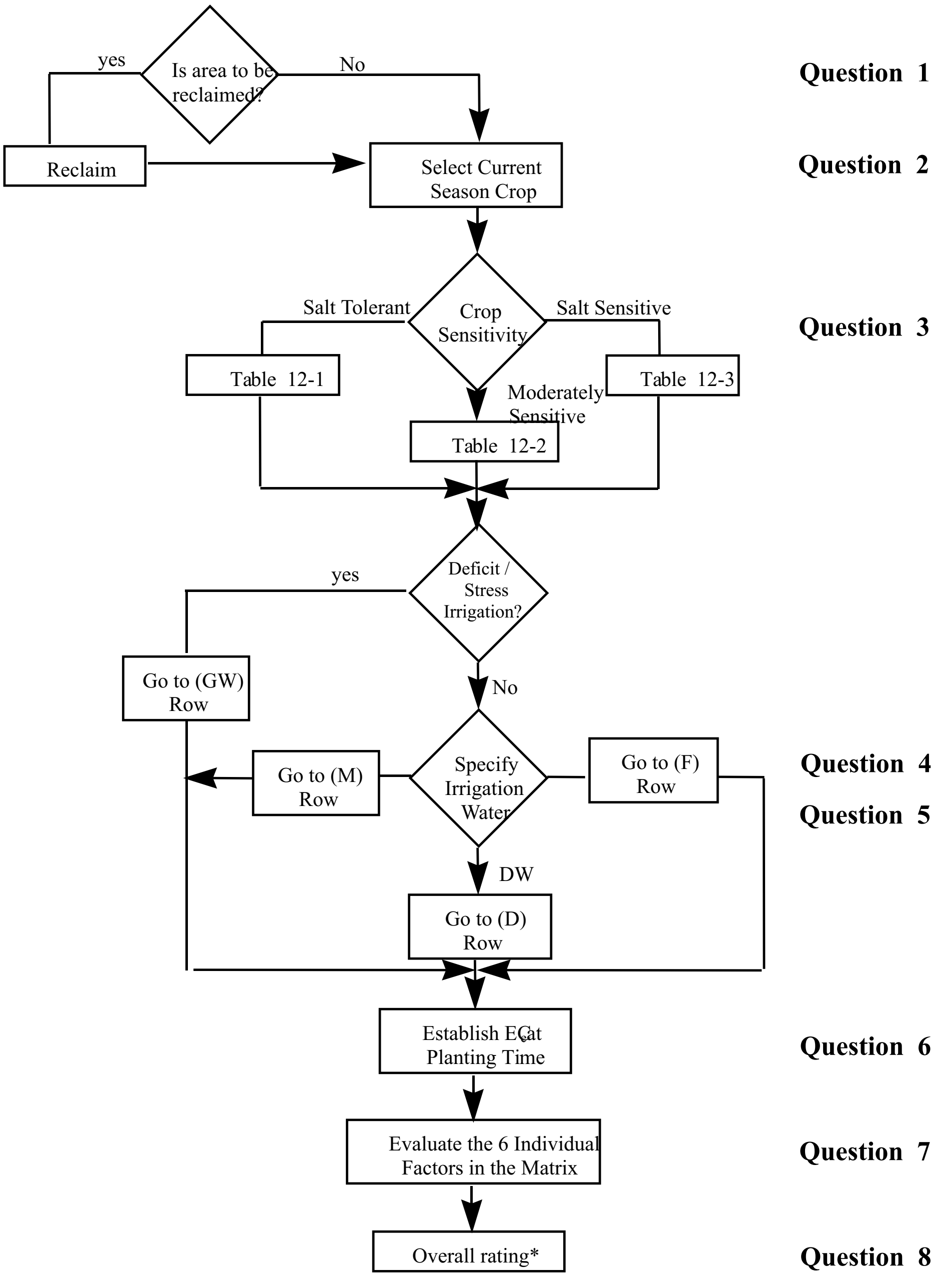

Fig 4. Chart Describing the Use of a Guidelines Matrix for Irrigation Water Management and Crop Production

Table 12 -1. Agricultural Guidelines Matrix for Salt Tolerant Crops

	Irrigation Water Quality		Irrigation Water Management	Soil Quality		
	Subfactor 1	Subfactor 2	Subfactor 3	Subfactor 4	Subfactor 5	Subfactor 6
Crop and Irrigation Water[1]	Productivity Cutoff ECiw	Productivity Cutoff SARiw	Irrigation Water Quantity[2]	Soil Salinitzation Potential[3,4]	Soil Dispersion Potential	ECe @ Planting[5]
Cotton(F)	Not applicable	SAR > 13	Consumptive use	no[6]	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Cotton(M)	6	SAR > 13	Consumptive use + LF	WT < 1m or restrictive layer[7] < 1 m and ECgw > 4 or LF < Fig. 7-2[8]	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Cotton(GW)	6	SAR > 13	Consumptive use	WT < 1m and ECgw > 4[9]	Refer to Figure5 Soil SAR > 13	>Productivity cutoff ECiw
Cotton(D)	6	SAR > 13	Consumptive use + LF	WT < 1m or restrictive layer[7] < 1m and ECgw > 4 or LF < Fig. 7-2[8]	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Wheat(F)	Not applicable	SAR > 13	Consumptive use	No	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Wheat(M)	4	SAR > 13	Consumptive use + LF	WT < 1m or restrictive layer < 1m or LF < Fig. 7-2	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Wheat(GW)	4	SAR > 13	Consumptive use	WT < 1m [9]	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw
Wheat(D)	4	SAR > 13	Consumptive use + LF	WT < 1m or restrictive layer < 1m or LF < 40	Refer to Figure 5 Soil SAR > 13	>Productivity cutoff ECiw

[1]By assumption ECiw : D > M > F; GW is stress irrigation and F is < 400 ppm total dissolved solids.
(F - Fresh water, M - Mixed fresh water and drainage water, D - Drainage water, GW - Ground water)
[2]This is the quantity of water necessary over the cropping season to maintain crop production at optimum level regarding soil-plant water relationships. The leaching fraction (LF) will vary based on salt tolerance of crop and irrigation water salinity. Use Figure 4
[3]Not applicable to sandy soil.
[4]Salinization potential is relative to the current crop and rotation.
[5]ECe @ Planting is that measured at the time of planting, or taken as equal to the EC_{iw} at the end of the previous season's irrigation. It must not be greater than the productivity cutoff of the new crop.
[6]A “No” because with freshwater the LF needed for salt tolerant crops is so low that irrigation inefficiencies will maintain an adequate LF.
[7]Restrictive layer: soil layer with clay texture, tillage pan, or other water restrictive layer.
[8]If ECiw is > crop productivity cutoff value (subfactor 1) **and** the LF needed to maintain average rootzone salinity at or below the ECiw cutoff value based on ECiw is not met, salinization detrimental to the current crop and any subsequent crop of equal or lesser salt tolerance is possible. Refer to Fig. 4 to determine average rootzone soil salinity for given ECiw. WT= water table
[9]Leaching fraction not applicable with stress irrigation; ECgw taken as approximately 0.60 (i. e. 1-LF) of ECiw; ECgw left out as criteria for all but cotton, as it was not a significant parameter in explaining soil salinity in the monitoring data, and values are almost always > 2 dS/m . Therefore, for the more salt-tolerant crops like wheat, less restrictive criteria were set by dropping the ECgw requirement. In addition, for the salt tolerant crops (i.e. cotton) most soil ECe's in the monitoring data were < ECgw that corresponds to a soil ECe of <6. In other words, the ECgw distribution is skewed significantly towards soils with an ECe of <6, reflecting less potential salinization in cotton from saline groundwater

Table 12 -2. Agricultural Guidelines Matrix for Moderately Salt Tolerant Crops

	Irrigation Water Quality		Irrigation Water Management	Soil Quality		
	Subfactor 1	Subfactor 2	Subfactor 3	Subfactor 4	Subfactor 5	Subfactor 6
Crop and Irrigation Water[1]	Productivity Cutoff ECiw	Productivity Cutoff SARiw	Irrigation Water Quantity[2]	Soil Salinization Potential[3,4]	Soil Dispersion Potential	ECe @ Planting[5]
Maize(F)	Not applicable	9	Consumptive use	LF < 5[10]	Refer to Figure 5Soil SAR > 10	>Productivity cutoff ECiw
Maize(M)	1.7	9	Consumptive use + LF	ECiw > 1.7 or ECgw > 10[6] or WT <1 m or restrictive layer[7] < 1 m or LF < Fig. 5	Refer to Figure 5 Soil SAR > 10	>Productivity cutoff ECiw
Maize(GW)	1.7	9	Consumptive use	WT <1 m[9]	Refer to Figure 5 Soil SAR > 10	>Productivity cutoff ECiw
Maize(D)	1.7	9	Consumptive use + LF	ECiw > 1.7 or ECgw >10[6] or WT < 1 m or restrictive layer < 1 m or LF < Fig. 5	Refer to Figure 5 Soil SAR > 10	>Productivity cutoff ECiw
Rice(F)	Not applicable	13	Flood	No	Not applicable	>Productivity cutoff ECiw
Rice(M)	3	13	Flood	ECiw > 3	Not applicable	>Productivity cutoff ECiw
Rice(GW)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	>Productivity cutoff ECiw
Rice(D)	3	13	Flood	ECiw >3	Not Applicable	>Productivity cutoff ECiw

By assumption ECiw : D > M > F; GW is subirrigation and F is < 400 ppm total dissolved solids.

[1]F - Fresh water, M - Mixed fresh water and drainage water, D - Drainage water, GW - Ground water

[2] This is the quantity of water necessary over the cropping season to maintain crop production at optimum level regarding soil-plant-water relationships. Leaching fraction (LF) will vary based on salt tolerance of crop and irrigation water salinity. Use Figure 5.

[3]Not applicable to sandy soil.

[4] Salinization potential is relative to the current crop and rotation.

[5]ECe @ planting is that measured at the time of planting, or taken as equal to the EC_{iw} at the end of the previous season's irrigation. It must not be greater than the productivity cutoff of the new crop.

[6]ECgw value derived from assessment of middle-delta monitoring data suggesting that in maize with values of >10 dS/m there is a greater likelihood of having soil EC's above 3 dS/m, even for deep water tables (> 1m). Therefore, a more restrictive criterion was chosen.

[7]Restrictive layer: soil layer with clay texture, tillage pan ,or other water restrictive layer.

[8]If ECiw is > crop productivity cutoff value (subfactor 1) **and** the LF needed to maintain average rootzone salinity at or below the ECiw cutoff value based on ECiw is not met, salinization detrimental to the current crop and any subsequent crop of equal or lesser salt tolerance is possible. Refer to Fig. 5 to determine average rootzone soil salinity for given ECiw. WT = water table

[9]No ECgw criteria, as ECgw generally ranges greater than the maize productivity cutoff value (based on monitoring data). Therefore, any elevated groundwater table poses a potential salinity hazard for maize. Elevated groundwater tables would probably be normal for stress irrigation (GW).

[10]Based on the freshwater ECiw of 0.4 dS/m, as per the definition of fresh irrigation water.

Table 12 -3. Agricultural Guidelines Matrix for Salt Sensitive Crops

	Irrigation Water Quality		Irrigation Water Management	Soil Quality		
	Subfactor 1	Subfactor 2	Subfactor 3	Subfactor 4	Subfactor 5	Subfactor 6
Crop and Irrigation Water1	Productivity Cutoff ECiw	Productivity Cutoff SARiw	Irrigation Water Quantity2	Soil Salinization Potential3, 4	Soil Dispersion Potential	ECe @ Planting5
Faba(F)	1	SAR > 5	Consumptive use	LF < 106	Refer to Figure 6 Soil SAR > 5	>Productivity cutoff ECiw
Faba(M)	1	SAR > 5	Consumptive use + LF	ECiw > 1 or WT <1 m or restrictive layer7 < 1 m or LF < 408	Refer to Figure 6 Soil SAR > 5	>Productivity cutoff ECiw
Faba(GW)	1	SAR > 5	Consumptive use	WT < 1m9	Refer to Figure 6 Soil SAR > 5	>Productivity cutoff ECiw
Faba(D)	1	SAR > 5	Consumptive use + LF	ECiw > 1 or WT <1 m or restrictive layer < 1 m or LF < 40	Refer to Figure 6 Soil SAR > 5	>Productivity cutoff ECiw
Berseem(F)	1.5	SAR > 10	Consumptive use	LF < 5	Refer to Figure 6 Soil SAR > 10	>Productivity cutoff ECiw
Berseem(M)	1.5	SAR > 10	Consumptive use + LF	ECiw > 1.5 or WT <1 m or restrictive layer < 1 m or LF < 40	Refer to Figure 6 Soil SAR > 10	>Productivity cutoff ECiw
Berseem(GW)	1.5	SAR > 10	--	WT < 1 m	Refer to Figure 6 Soil SAR > 10	>Productivity cutoff ECiw
Berseem(D)	1.5	SAR > 10	Consumptive use + LF	ECiw > 1.5 or WT <1 m or restrictive layer < 1 m or LF < 40	Refer to Figure 6 Soil SAR > 10	>Productivity cutoff ECiw

[1] By assumption ECiw : D > M > F; GW is subirrigation and F is < 400 ppm total dissolved solids.
(F - Fresh water, M - Mixed fresh water and drainage water, D - Drainage water, GW - Ground water)

[2] This is the quantity of water necessary over the cropping season to maintain crop production at optimum level regarding soil-plant-water relationships. Leaching fraction (LF) will vary based on salt tolerance of crop and irrigation water salinity. Use Figure 5.

[3] Not applicable to sandy soil.

[4] Salinization potential is relative to current crop and rotation.

[5] ECe @ Planting is that measured at the time of planting, or taken as equal to the EC_{iw} at the end of the previous season's irrigation. It must not be greater than the productivity cutoff of the new crop.

[6] Based on the freshwater ECiw of 0.4 dS/m as per the definition of fresh irrigation water.

[7] Restrictive layer: soil layer with clay texture, tillage pan ,or other water restrictive layer.

[8] If ECiw is > crop productivity cutoff value (subfactor 1) **and** the LF needed to maintain average rootzone salinity at or below the ECiw cutoff value is not met, salinization detrimental to the current crop and any subsequent crop of equal or lesser salt tolerance is possible. Criteria set at more restrictive LF of < 40 based on assuming ECiw is near productivity cutoff value for mixed or drainage water.

[9] No ECgw criteria, as ECgw generally ranges greater than the faba or berseem productivity cutoff value (based on monitoring data). Therefore, any elevated groundwater table poses a potential salinity hazard for maize. Elevated groundwater tables would probably be normal for stress irrigation (GW).

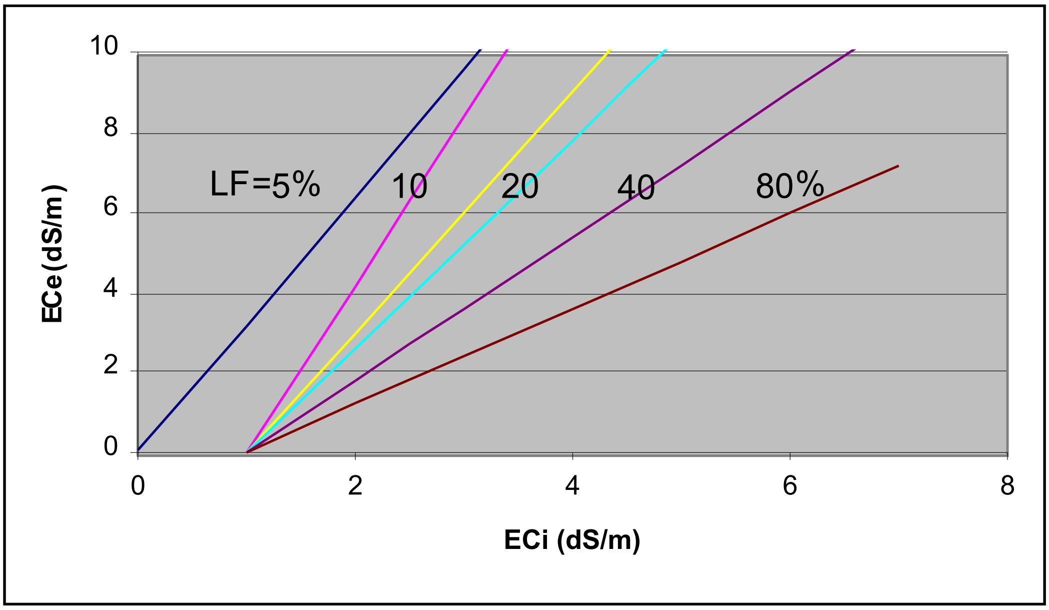

Fig 5. Agricultural Salinity and Drainage by Blaine Hanson et al (1993)

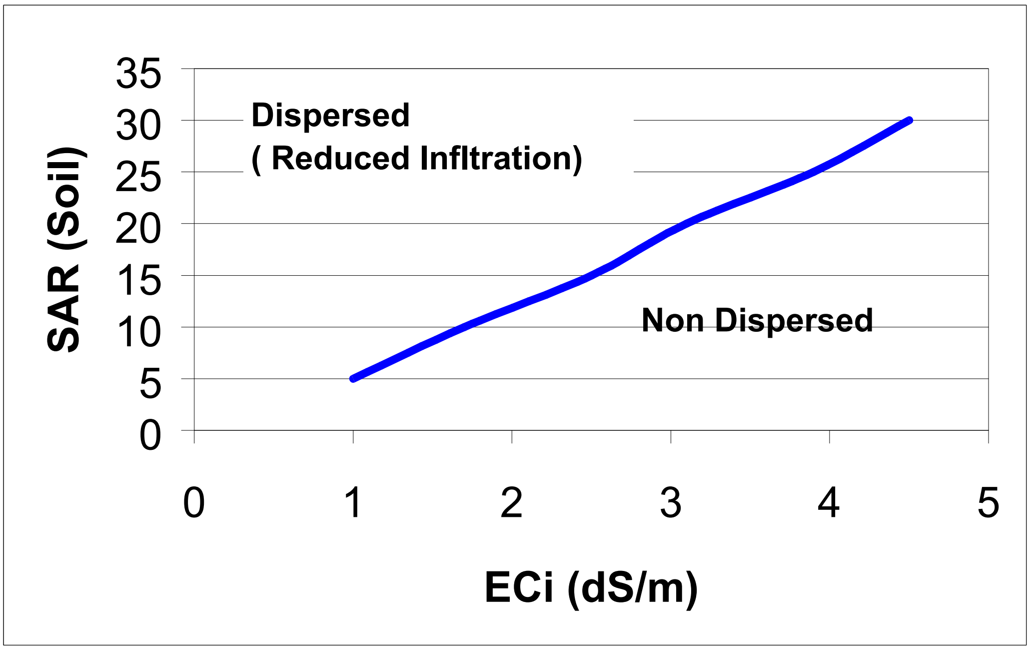

Fig 6: Agricultural Salinity and Drainage by Blaine Hanson et al (1993)
Water Infiltration Rate as Affected by Salinity and Sodium Absorption Ratio SAR-Soil

Conclusions and Recommendations

The regular monitor the effect of reuse of different types of drainage water used for irrigation under different management policies on the accumulation of salts and other harmless or harmful substances in the soil profile as well as the effect on the toxicity of crops especially those eaten raw by humans for animals. This activity has not started yet, and a complete research program has to be formulated and to start soon. Being capable of obtaining historic and present situation with regard to drainage water quantity and quality, getting sound estimates of the change in these parameter with the possible changes in the existing conditions and being aware of the effect of using this water for the irrigation of different crops grown in different soils and under different climatic conditions, this whole set up of information covers the complete picture and enables taking the proper decision at the proper time.

Farmer participation in irrigation schemes especially in newly reclaimed areas has become synonymous with the decentralization of water management strategy. From the extension services provided by MWRI in the irrigation improvement projects, currently farmers in the desert and newly reclaimed areas are willing to engage in organization (from local areas) for water user associations. This organization should provide services on management of all water resources in the areas till the field level. This success factor of the ongoing activity of this organization will be farmer personal benefits. Because of building a sustainable organization require a time and support of different agencies; the current experimental area is considered to be in the designed phase of water user associations and needs to be supported in a significant institution framework to be able to achieve sustainable water management in different stress and low water quality conditions.

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