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# Evaluation of Irrigation Water, Drainage Water, Soil Salinity, and Groundwater for Sustainable Cultivation

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**Abstract**

Use low-quality water has become part of Egypt water strategies to meet its demands especially in the agricultural sector. This study investigates the irrigation water (mixed freshwater with agricultural drainage water), drainage water, soil drainage, salinity and groundwater for Gelbana region (2500 hectare new reclaimed area since 2000) at the East South El-Qantara, North Sinai, Egypt. The findings indicated that irrigation water quality was slightly saline. The drainage water and groundwater were medium saline. Soil was a poorly medium dense sand, have an electrical conductivity (EC) varying from 1 to 4 dS/m, and the vertical drainage was low efficiency. for sustainable cultivation it is recommended that (1) applying subsurface drainage system to improve washing of soil salts (2) changing the cropping system at the scheme to meet soil salinity levels (3) periodic monitoring for the irrigation water, drainage water, soil salinity, and the groundwater are important issue to manage crop pattern and drainage water.

**Keywords:** Groundwater monitoring; Irrigation water; Soil salinity; Subsurface drainage

## Introduction

Various problems such as increasing soil salinity, water logging and rising groundwater levels in the effective root zone were raised when effective drainage conditions are not provided for the irrigated area [1]. An effective drainage system removes additional salts into irrigation-treated soils. Drainage networks should be practiced in conjunction with irrigation networks to ensure maximum yields and environmental safety for the irrigation projects [2-4]. Surface drainage eliminates extra water collected in the cropped area; the subsurface drainage system is extra effective than the surface drainage in removing salt in the soil strata [5-7]. Reused drainage water has low quality in irrigation contain increased levels of salts, heavy metals, toxic ions, and pesticides. In the Nile Delta, the most serious risk to sustainable agriculture comes from the recycling of salts by the reuse of drainage water [8]. Increased sodicity and higher levels of the total suspended solids, and the dissolved organic matter are more harmful effects on soil physical properties; therefore, the soil hydraulic conductivity will be decreased and so yield decrease [9-11]. Constant monitoring for the soil and irrigation water is a very important issue especially in case of low water quality (reused agriculture drainage water and blending agriculture drainage wastewater with freshwater). Such analysis help to determine the problem of soil salinity before the problem comes out of control and steps are taken to deal with these problems. In addition, field data on differences in irrigation water quality and soil salinity over time is necessary when recommending changes in the cropping system equivalent to both water and soil salinity levels [12]. This study was conducted to assess irrigation water quality (Nile freshwater mixed with agriculture drainage wastewater), soil drainage, and soil salinity for Gelbana region (new reclaimed area of 2500 hectare cultivated since 2000), East South El-Qantara, North Sinai, Egypt. In addition, to recommend if there was a requirement to apply subsurface drainage network (currently surface drainage network is applied) or to change the cropping scheme according to measured soil salinity levels.

## Materials and Methods

In this study, the Gelbana area in the East South El-Qantara region, North Sinai, Egypt was selected to be a study case (Figure 1). It is a new reclaimed and cultivated area (2500 hectare), which has been operated by Water Resources, Irrigation and Infrastructures Sector, North Sinai, Ministry of Water Resources and Irrigation (MWRI) Egypt since 2000. The studied area is characterized by a semi-arid climate. The topography is sand terrain with large differences in elevations and steep slopes. The highest elevation is 22 m and the lowest elevation is 2.0 m above mean sea level. Irrigation water leakage has increased and accumulated in low elevation regions. The applied irrigation systems are sprinkler irrigation and drip irrigation. The surface drainage networks were implemented at the same time with irrigation facilities. The subsurface drainage networks did not implement tell now. Wheat, sugar beet and corn are the main crops grown in the area, in addition, vegetables and fruits. The irrigation water in the study area is Nile freshwater mixed with agriculture drainage wastewater in a ratio 1:1 with salinity up to 1000 ppm. The main feeder canal is Garib Attwa Canal (Figure 1), which takes its water from the South East EL-Qantara Canal, surface drainage network consists of Main Gelbana Drain linked with Branch Gelbana Drain [13,14].

### Water sampling

During the period from September 2013 to August 2014, water samples from irrigation canals, drainage canals, and groundwater observation wells were taken and analyzed, by Drainage Research Institute, National Water Research Center, MWRI, Egypt. September was chosen to be appropriate considering the report by Rhoades [15] where it was found that this month is the time when the consumption of plant water is higher. Monthly irrigation water samples were taken from three monitoring locations, in the beginning, middle and the lower parts of the Garib Attwa Canal were named GH. Drainage water samples were taken from five monitoring locations in the Major Gelebana Drain was named G and two points in Gelbana Branch Drain were named GB Figure 2. When taking water samples principles in APHA [16] were considered and the water samples were sent to the Center Laboratory for Environmental Quality Monitoring, National

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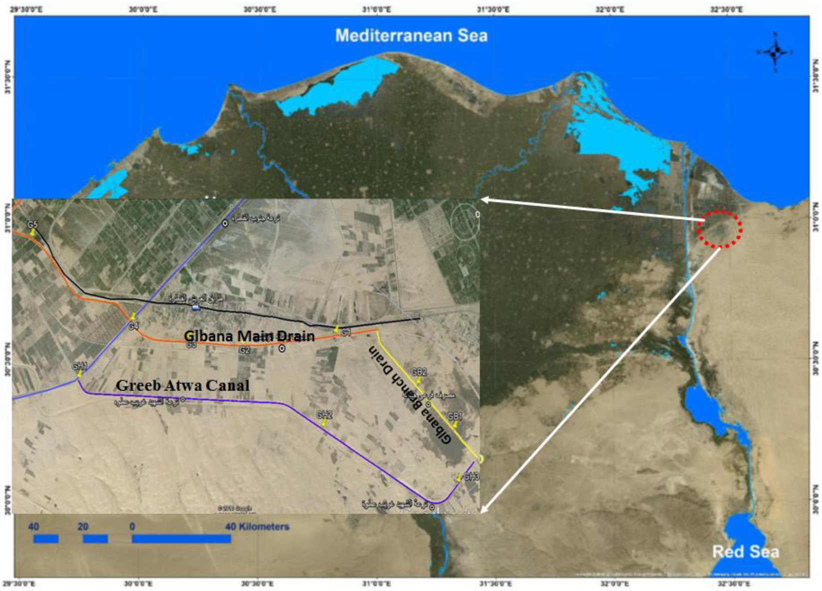


**Figure 1:** The studied area location.

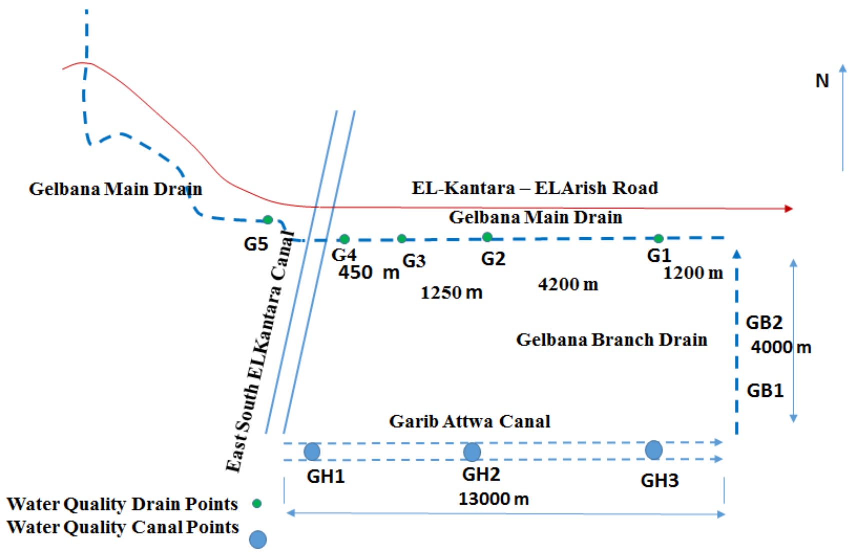


**Figure 2:** Water quality monitoring locations for the studied canals and drains.

Water Research Center, MWRI, Cairo, Egypt. The analysis for physical and chemical water parameters, (PH, EC, and TDS), Main Cations (Ca, Mg, Na, K, B), Main Anion ($CO_3$, Cl, $HCO_3$, $SO_4$, $No_3$), and Sodium adsorption ratio (SAR) were carried out according to the method of authors [16].

## Surface groundwater monitoring

A 65 surface observation wells distributed over the study were implemented to determine surface groundwater quality and the extent of the water levels changing (Figure 3). The water levels were recorded by automatic level and water samples were taken during the period from September 2013 to August 2014 and analyzed for physical and chemical parameters, PH, and electrical conductivity (EC).

## Water quality evaluation

The leaching of soluble salts from the root depth is essential in irrigated soils to prevent the accumulation of the salts resulting from the extraction of moisture from the soil by the processes of evaporation and transpiration. To measure water quality, following guides were calculated using the shown equations and water quality criteria:

1. Sodium adsorption ratio (SAR), [17].

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

In eqn. (1), where: [ions units in Milliequivalents per liter (meq/liter)].

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**Figure 3:** Distribution of the locations of the monitoring wells.

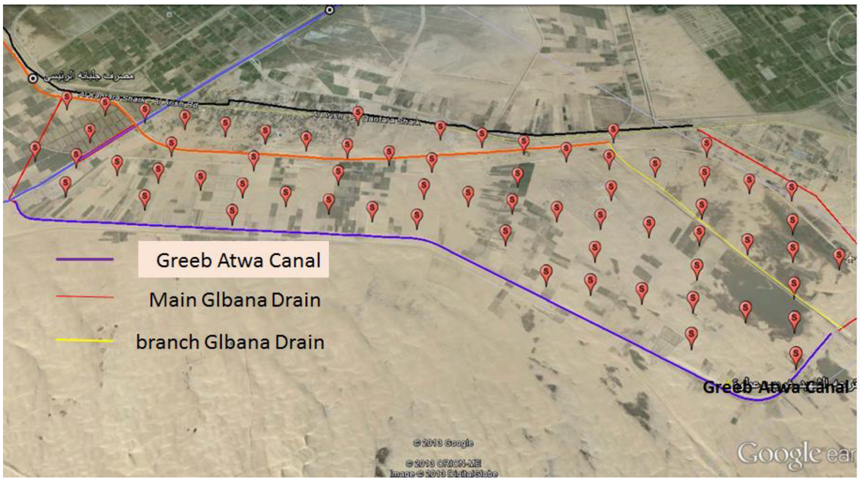


**Figure 4:** Distribution of the soil boreholes locations.

Standards: for SAR <10, excellent (S1), SAR=10–18 good (S2), SAR=18–26 doubtful (S3), and SAR >26 improper (S4).

2. Total dissolved solids (TDS)

TDS in (mg/liter)=K × EC (2)

In eqn. (2), where: EC is the electrical conductivity (dS/m), K=640 for most of the cases, K=735 for mixed waters, and

K=800 for EC > 5 dS/m. Criteria: TDS <1,000 non-saline, TDS=1,000–3,000 slightly saline, TDS=3,000–10,000 moderately saline, and TDS >10,000 very saline [17].

## Soil sampling

A group of 87 boreholes randomly distributed in the studied area Figure 4 was carried out for soil depth up to 3 m. The samples have collected for the depths from 0.00 – 50 cm, 50 – 100 cm, and from 100 – 300 cm. The soil properties analysis for the samples (mechanical analyses, density, voids ratio, specific gravity, and permeability) were carried out according to author. The analysis for physical and chemical soil solution parameters, ( PH, EC, and TDS), Main Cations (Ca, Na, Mg, K), Main Anion ($HCO_3$, $Co_3$, Cl, $SO_4$), exchangeable sodium percent (ESP) and SAR for the soil layers were carried out agreeing to the method of FAO [15]. Statistical analysis was carried out for the physicochemical parameters results of 355 soil samples taken from different depths and locations. In addition, it presented in Tables 4 and 5. Figure 5 shows the results of soil permeability distribution for the study area. Figures 6-8 show the distribution of electrical conductivity (EC) in dS/m for soil at depths from 0.00 to 50 cm, 50 cm to 100 cm, and 150 cm to 200 cm.

# Results and Discussion

## Assessment of the water quality for irrigation and drainage canals

The statistics for the results of water physical and chemical parameters for the sites on the main irrigation canal Greeb Atwa are

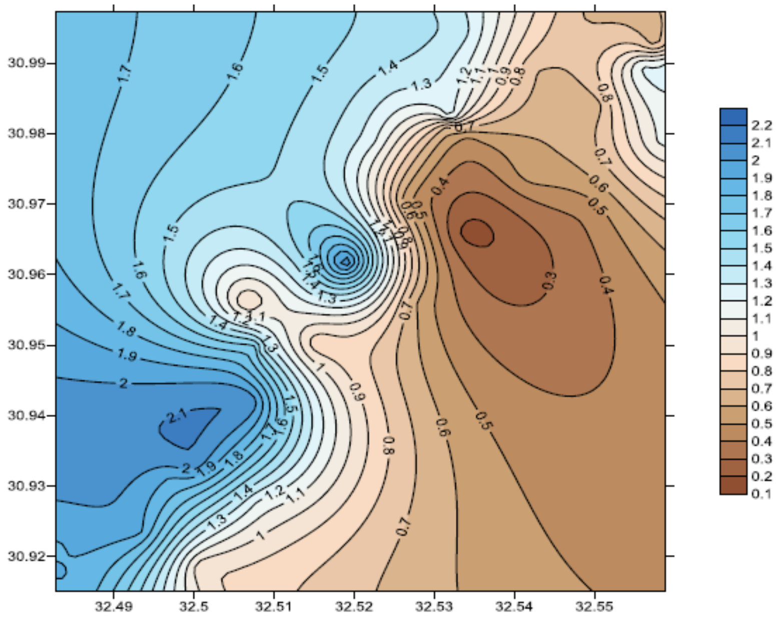


**Figure 5:** Soil permeability distribution for the study area

**Figure 6:** Electrical conductivity (EC) distribution in dS/m for the soil depth from 0.00 to 50 cm.

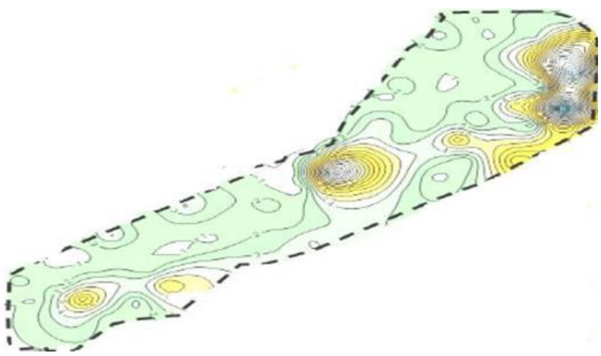

**Figure 7:** Electrical conductivity (EC) distribution in dS/m for the soil depth from 50 cm to 100 cm.

shown in Table 1, PH concentrations have no significant difference where minimum PH is 7.60, maximum is 7.86, and the median is 7.78. No significant difference in EC concentration, where minimum EC value is 2.28 dS/m, maximum is 2.71 dS/m and the median is 2.55 dS/m. The SAR is a good indicator of the sodium hazard in soil and water, the minimum SAR is 5.5, maximum is 7.5 and the median is 6.17. The measured EC concentrations were in the limits of The Egypt Decree 92/2013, Administrative Regulation of Law 48/1982 safeguards freshwater watercourses from pollution by the discharged effluents. The irrigation water quality is classified as, slightly saline water-no sodium risk or any acute toxic problem-under good management and on light soil with good structure and internal drainage; it is suitable for use in most crops.

The results of the statistical physical and chemical water parameters

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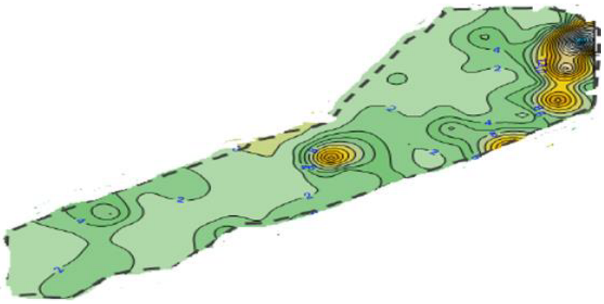

**Figure 8:** Electrical conductivity (EC) distribution in dS/m for the soil depth from 150 cm to 200 cm.

| | | | | | |
|---|---|---|---|---|---|
| **Ghreeb Atwa Irrigation Canal** | | | | | |
| **Electrical conductivity EC dS/m** | | | | **pH** | |
| Min.=2.28 | | | | Min.=7.60 | |
| Max.=2.71 | | | | Max.=7.86 | |
| Median:=2.55 | | | | Median=7.78 | |
| **SAR** | | | | | |
| Min.=5.50 | | | | | |
| Max.=7.50 | | | | | |
| Median=6.17 | | | | | |
| **Anions** | **mg/l*** | **meq/l**** | **Cations** | **mg/l** | **meq/l** |
| **Chloride ($Cl^-$)** | | | **Sodium ($Na^+$)** | | |
| Min. | 355 | 10 | Min. | 230 | 10 |
| Max. | 533 | 15 | Max. | 345 | 15 |
| Median | 391 | 11.0 | Median | 253 | 11 |
| **Sulphate ($SO^4$)** | | | **Potassium ($K^+$)** | | |
| Min. | 115 | 2.39 | Min. | 4 | 0.1 |
| Max. | 556 | 11.59 | Max. | 5 | 0.13 |
| Median | 485 | 10.10 | Median | 4 | 0.11 |
| **Carbonate ($CO_3^{--}$)** | | | **Calcium ($Ca^{++}$)** | | |
| Min. | Nil | Nil | Min. | 97 | 4.86 |
| Max. | Nil | Nil | Max. | 122 | 6.12 |
| Median | Nil | Nil | Median | 113 | 5.64 |
| **Bicarbonate ($HCO_3^-$)** | | | **Magnesium ($Mg^{++}$)** | | |
| Min. | 183 | 3.0 | Min. | 40 | 3.30 |
| Max. | 275 | 4.5 | Max. | 59 | 4.85 |
| Median | 214 | 3.5 | Median | 53 | 4.38 |
| **Nitrate ($NO_3^-$)** | | | **Boron (B)** | | |
| Min. | 157 | 2.53 | Min. | Nil | Nil |
| Max. | 246 | 3.97 | Max. | Nil | Nil |
| Median | 187 | 3.01 | Median | Nil | Nil |
| **Total** | | | | | |
| Min. | 810 | 17.92 | | 371 | 18.26 |
| Max. | 1609 | 35.06 | | 532 | 26.13 |
| Median | 1275 | 27.61 | | 424 | 21.13 |
| **TDS:** | | | | | |
| Min. | 1181 | | | | |
| Max. | 2141 | | | | |
| Median | 1699 | | | | |

* Milligram per liter (mg/l or ppm)
**Mill equivalents per liter (meq/l).

**Table 1:** Statistical parameters for water samples results of Ghreeb Atwa irrigation canal.

for Main Gelbana Drain are shown in Table 2, PH concentrations have no significant difference where minimum PH is 7.53, maximum is 7.71 and the median is 7.61.

A significant difference in EC concentrations, where minimum EC value is 2.29 dS/m, maximum is 16 dS/m and the median is 4.24 dS/m. The sodium adsorption ratio (SAR), minimum is 7.07, maximum is 9.17 and the median is 8.25. The difference of the EC values back to the land topography, where water accumulated in the low land, evaporation of water from low lands increase water salinity with time. The measured EC concentrations were in the limits of the Egypt Decree

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| **Main Gelbana Drain** | | | | | |
|---|---|---|---|---|---|
| **Electrical conductivity EC dS/m** | | | | **pH** | |
| Min.=2.9 | | | | Min.=7.53 | |
| Max.=16 | | | | Max.=7.71 | |
| Median:=4.24 | | | | Median=7.61 | |
| **SAR** | | | | | |
| Min.=7.07 | | | | | |
| Max.=9.17 | | | | | |
| Median=8.25 | | | | | |
| **Anions** | **mg/l** | **meq/l** | **Cations mg/1** | **mg/l** | **meq/l** |
| **Chloride ($Cl^-$)** | 609 | 17.16 | **Sodium ($Na^+$)** | 389 | 16.93 |
| Min. | | | Min. | | |
| Max. | 5172 | 145.7 | Max. | 2530 | 110 |
| Median | 902 | 25.4 | Median | 474 | 20.63 |
| **Sulphate ($SO_4$)** | 485 | 10.11 | **Potassium ($K^+$)** | 3 | 0.08 |
| Min. | | | Min. | | |
| Max. | 832 | 17.34 | Max. | 7 | 0.17 |
| Median | 630 | 13.13 | Median | 4 | 0.11 |
| **Carbonate ($CO_3^{--}$)** | Nil | Nil | **Calcium ($Ca^{++}$)** | 102 | 5.12 |
| Min. | | | Min. | | |
| Max. | Nil | Nil | Max. | 814 | 40.7 |
| Median | Nil | Nil | Median | 168 | 8.4 |
| **Bicarbonate ($HCO_3^-$)** | 130 | 2.14 | **Magnesium ($Mg^{++}$)** | 49 | 4.02 |
| Min. | | | Min. | | |
| Max. | 354 | 5.8 | Max. | 378 | 31 |
| Median | 286 | 4.69 | Median | 65 | 5.3 |
| **Nitrate ($NO_3^-$)** | 134 | 2.16 | **Boron (B)** | Nil | Nil |
| Min. | | | Min. | | |
| Max. | 215 | 3.47 | Max. | Nil | Nil |
| Median | 186 | 3.01 | Median | Nil | Nil |
| **Total** | 1358 | 31.57 | | | |
| Min. | | | | 544 | 26.15 |
| Max. | 6573 | 172.31 | | 3729 | 181.87 |
| Median | 2005 | 46.23 | | 711 | 34.44 |
| **TDS:** | 1902 | | | | |
| Min. | | | | | |
| Max. | 10302 | | | | |
| Median | 2716 | | | | |

**Table 2:** Statistical parameters for water samples results of Main Gelbana drain.

92/2013. According to Kenneth and Neeltje [1] the drainage water quality is medium saline water; there is no sodium risk under good management, on light soil with good infiltration, internal drainage, and a previous layer.

The results of the statistical physical and chemical water parameters for Branch Gelbana Drain are shown in Table 3, PH concentrations have no significant difference where minimum is PH 7.54, maximum is 7.66, and the median is 7.62. No significant differences in EC concentrations where minimum EC value is 3.30 dS/m, maximum is 4.5 dS/m and the median is 3.9 dS/m. The sodium adsorption ratio (SAR), minimum 7.07, maximum is 9.17 and the median is 8.25. The measured EC concentrations were in the limits of the Local Egypt Decree, 2013. According to Kenneth and Neeltje [1] the drainage water quality is medium saline water; there is no sodium risk under good management, on light soil with good infiltration, internal drainage, and a previous layer. Periodic monitoring for the quality of irrigation water and drainage water is an important issue for the new land reclamation and cultivation projects that use slightly saline water resources, where the results of monitoring data help to select the proper crop pattern, managing drainage water salinity, and minimizing negative environmental impact on reclaimed land.

## Evaluation of soil

**Soil properties:** The results of main soil properties were the particle size distribution was determined using the dry sieving method. The effective diameter (D10) was 0.50 mm; the mean diameter (D50) was 3.388 mm; uniformity coefficient (Cu) was 3.388 and the coefficient of curvature (Cc) was 0.99. The soil was classified as poorly medium dense sand. The specific gravity of the sand particles was determined by the gas jar method resulting from an average value of 2.65. The maximum dry density was 19.6 $KN/m^3$ at voids ratio 34 % and the minimum dry density was 16.1 $KN/m^3$ at voids ratio 62 %. Figure 5 shows soil permeability distribution for the studied area, the mean value for the coefficient of soil permeability for the western region was 1.69 m/day, for the middle region was 0.87 m/day, and for the eastern region was 0.79 m/day, semi-permeable soil [1].

**Soil salinity:** Table 4 shows the statistical parameters for soil salinity results at depth 0.0 – 50 cm, PH concentrations have no significant difference where minimum PH is 7.40, maximum is 8.27, and the average is 7.89. A significant difference in EC concentrations, where minimum EC value is 0.5 dS/m, maximum is 93.4 dS/m and the average is 4.79 dS/m. The sodium adsorption ratio (SAR),

| Brach Gelbana Drain Canal | | | | | |
|---|---|---|---|---|---|
| Electrical conductivity EC dS/m | | | | pH | |
| Min.=3.3 | | | | Min.=7.54 | |
| Max.=4.5 | | | | Max.=7.66 | |
| Median:=3.9 | | | | Median=7.62 | |
| SAR | | | | | |
| Min.=7.07 | | | | | |
| Max.=9.17 | | | | | |
| Median=8.25 | | | | | |
| **Anions** | **mg/l** | **meq/l** | **Cations** | **mg/l** | **meq/l** |
| **Chloride ($Cl^-$)** | | | **Sodium ($Na^+$)** | | |
| Min. | 609 | 19.21 | Min. | 389 | 16.93 |
| Max. | 5172 | 25.4 | Max. | 2530 | 20.51 |
| Median | 902 | 21.14 | Median | 474 | 19.48 |
| **Sulphate ($SO_4$)** | | | **Potassium ($K^+$)** | | |
| Min. | 485 | 10.11 | Min. | 3 | 0.09 |
| Max. | 832 | 14.36 | Max. | 7 | 0.13 |
| Median | 630 | 12.6 | Median | 4 | 0.11 |
| **Carbonate ($CO_3^{--}$)** | | | **Calcium ($Ca^{++}$)** | | |
| Min. | Nil | Nil | Min. | 102 | 5.12 |
| Max. | Nil | Nil | Max. | 814 | 8.4 |
| Median | Nil | Nil | Median | 168 | 6.32 |
| **Bicarbonate ($HCO_3^-$)** | | | **Magnesium ($Mg^{++}$)** | | |
| Min. | 130 | 4.69 | Min. | 49 | 4.02 |
| Max. | 354 | 5.8 | Max. | 378 | 5.3 |
| Median | 286 | 5.45 | Median | 65 | 4.42 |
| **Nitrate ($NO_3^-$)** | | | **Boron (B)** | | |
| Min. | 134 | 2.16 | Min. | Nil | Nil |
| Max. | 215 | 3.47 | Max. | Nil | Nil |
| Median | 186 | 3.01 | Median | Nil | Nil |
| **Total** | | | | | |
| Min. | 1587 | 36.17 | | 544 | 26.16 |
| Max. | 2160 | 49.03 | | 709 | 34.34 |
| Median | 1874 | 42.2 | | 633 | 30.33 |
| **TDS:** | | | | | |
| Min. | 2132 | | | | |
| Max. | 2869 | | | | |
| Median | 2507 | | | | |

**Table 3:** Statistical parameters for water samples results of Brach Gelbana Drain Canal.

| Soil samples results at depth 0.0 – 50 cm | | | | | |
|---|---|---|---|---|---|
| Electrical conductivity EC dS/m: | | | | pH: | |
| Min.=0.5 | | | | Min.=7.40 | |
| Max.=93.4 | | | | Max.=8.27 | |
| Average=4.79 | | | | Average=7.89 | |
| Median:=2.20 | | | | Median=7.88 | |
| SAR | | | | ESP | |
| Min.=2.40 | | | | Min.=0.50 | |
| Max.=42.83 | | | | Max.=8.25 | |
| Average=8.36 | | | | Average=1.71 | |
| Median=6.41 | | | | Median=1.33 | |
| **Anions** | **mg/l** | **meq/l** | **Cations** | **mg/l** | **meq/l** |
| **Chloride ($Cl^-$)** | | | **Sodium ($Na^+$)** | | |
| Min. | 609 | 2.3 | Min. | 82 | 3.56 |
| Max. | 5172 | 290 | Max. | 13756 | 598.08 |
| Average | 902 | 23.61 | Average | 474 | 30.79 |
| Median | 365.7 | 10.3 | Median | 708 | 13.67 |
| **Sulphate ($SO_4$)** | | | **Potassium ($K^+$)** | | |
| Min. | 5.28 | 0.11 | Min. | 5.9 | 0.15 |
| Max. | 38004 | 791 | Max. | 109 | 2.78 |
| Average | 1082 | 22.54 | Average | 23 | 0.64 |
| Median | 355 | 7.4 | Median | 25 | 0.6 |
| **Carbonate ($CO_3^{--}$)** | | | **Calcium ($Ca^{++}$)** | | |
| Min. | Nil | Nil | Min. | 14 | 0.68 |
| Max. | Nil | Nil | Max. | 3990 | 199.5 |
| Average | Nil | Nil | Average | 212 | 10.59 |
| Median | | | Median | 103 | 5.13 |
| **Bicarbonate ($HCO_3^-$)** | | | **Magnesium ($Mg^{++}$)** | | |
| Min. | 0 | 0 | Min. | 1.5 | 0.12 |
| Max. | 427 | 7 | Max | 1836 | 190.5 |
| Average | 212 | 3.47 | Average | 212 | 7.83 |
| Median | 232 | 3.8 | Median | 45 | 3.73 |
| **Total** | | | | | |
| Min. | 87 | 2.41 | | 103 | 4.51 |
| Max. | 48726 | 1089 | | 1836 | 151 |
| Average | 2132 | 49.62 | | 1041 | 49.85 |
| Median | 953 | 21.5 | | 486 | 23.13 |
| **TDS:** | | | | | |
| Min. | 190 | | | | |
| Max. | 68417 | | | | |
| Average | 3172 | | | | |
| Median | 1439 | | | | |

**Table 4:** Statistical parameters for soil salinity results at depth 0.00–50 cm.

minimum value is 2.40, maximum is 42.83 and the average is 8.36. The ESP minimum value is 0.52 dS/m, maximum is 5.81 dS/m, and the average is 1.54 dS/m. The difference of the EC values back to the land topography where water accumulated in the low land, evaporation of water from low lands increase water salinity with time. Table 5 shows the statistical parameters for soil salinity results at depth 50-100 cm, PH concentrations have no significant difference where, minimum is 7.40, maximum is 8.21, and the average is 7.89. Significant differences in EC concentrates, where minimum EC value is 0.31 dS/m, maximum is 28.4 dS/m and the average is 3.71 dS/m. The sodium adsorption ratio (SAR), minimum is 2.50, maximum is 29.36 and the average is 7.51. The ESP minimum value is 0.52 dS/m, the maximum is 5.81 dS/m, and the average value is 1.54 dS/m. Figure 6 shows the EC distributions for the soil depth from 0.00 - 50 cm, where EC for the Western region is ranged from 1 to 3 dS/m, the middle region is 3 to 4 dS/m, and for the Eastern region is 4 to 6 dS/m. The values of the EC are matched with the soil permeability distribution. Figure 7 shows the EC distribution for soil depth from 50-100 cm, where EC ranging from 1 to 3 dS/m except for small areas of low elevations in Western and middle regions and very small areas in the eastern region. Figure 8 shows the EC distribution for soil depth from 150-200 cm, where EC ranged from 1 to 3 dS/m except for very small areas of low elevations in western and middle regions. There are some depressions that accumulate water by seepage from surrounding plantation areas of high elevations and make water ponds. This means that for low elevation areas, the vertical drainage have low efficiency and it is insufficient to permit the washing of soil without the need for the implementation of subsurface drainage networks.

## Groundwater quality and levels

Figure 9 shows the groundwater levels for the studied area during the period from September 2013 to August 2014 where, many observation wells in the high elevation regions were dry, and the high groundwater levels were observed in the wells at low elevation regions adjacent to cultivated areas. The EC for the groundwater ranged from

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| | | | | | |
|---|---|---|---|---|---|
| **Soil samples results at depth 50–100 cm** | | | | | |
| **Electrical conductivity EC dS/m:** | | | | **pH:** | |
| Min.=0.31 | | | | Min.=7.4 | |
| Max.=28.4 | | | | Max.=8.21 | |
| Average=3.71 | | | | Average=7.89 | |
| Median:=2.57 | | | | Median=7.95 | |
| **SAR** | | | | **ESP** | |
| Min.=2.50 | | | | Min.=0.52 | |
| Max.=29.36 | | | | Max.=5.81 | |
| Average=7.51 | | | | Average=1.54 | |
| Median=5.83 | | | | Median=1.21 | |
| **Anions** | **mg/l** | **meq/l** | **Cations** | **mg/l** | **meq/l** |
| **Chloride ($Cl^-$)** | | | **Sodium ($Na^+$)** | | |
| Min. | 78.1 | 2.2 | Min. | 87.4 | 3.8 |
| Max. | 6993.5 | 197 | Max. | 4257.76 | 185.12 |
| Average | 768.6 | 21.65 | Average | 527.85 | 22.95 |
| Median | 418.9 | 11.8 | Median | 424.42 | 10.54 |
| **Sulphate ($SO_4$)** | | | **Potassium ($K^+$)** | | |
| Min. | 2.9 | 0.06 | Min. | 4.7 | 0.12 |
| Max. | 4975 | 103.7 | Max. | 55.5 | 1.42 |
| Average | 597.12 | 12.44 | Average | 21.9 | 0.56 |
| Median | 288 | 6 | Median | 21.11 | 0.54 |
| **Carbonate ($CO_3^{--}$)** | | | **Calcium ($Ca^{++}$)** | | |
| Min. | Nil | Nil | Min. | 22.6 | 1.3 |
| Max. | Nil | Nil | Max. | 1001.4 | 50.07 |
| Average | Nil | Nil | Average | 177.2 | 8.86 |
| Median | | | Median | 100 | 5 |
| **Bicarbonate ($HCO_3^-$)** | | | **Magnesium ($Mg^{++}$)** | | |
| Min. | 0 | 0 | Min. | 4.39 | 0.36 |
| Max. | 427 | 7 | Max | 468.8 | 38.43 |
| Average | 220.2 | 3.61 | Average | 36.6 | 3 |
| Median | 244 | 4 | Median | 65.15 | 5.34 |
| **Total** | | | | | |
| Min. | 81 | 2.26 | | 119 | 5.41 |
| Max. | 12395.7 | 307.7 | | 5783.5 | 275 |
| Average | 1586 | 37.7 | | 972 | 37.71 |
| Median | 951 | 21.8 | | 400.1 | 19.08 |
| **TDS:** | | | | | |
| Min. | 200 | | | | |
| Max. | 18179.2 | | | | |
| Average | 2378 | | | | |
| Median | 1351.1 | | | | |

**Table 5:** Statistical parameters for soil salinity results at depth 50 –100 cm.

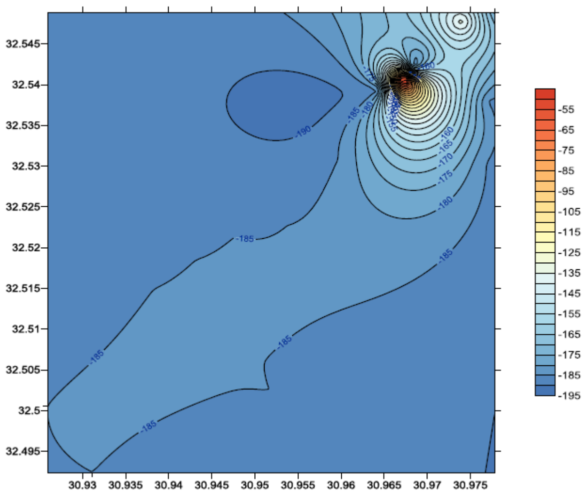


**Figure 9:** Groundwater levels for the study area

| Well number | Time of measurements | Constant (cm) | Groundwater depth measured from the top of the well (cm) | Groundwater depth measured from the ground surface (cm) | EC (dS/m) | PH |
|---|---|---|---|---|---|---|
| **S6** | September-2013 | 15 | 195 | 180 | 1.43 | 7.59 |
| | Nonmember -2013 | 15 | 191 | 176 | 1.53 | 7.58 |
| | Desember-2013 | 15 | 190 | 175 | 1.52 | 7.63 |
| | January-2014 | 15 | 186 | 171 | 1.5 | 7.62 |
| | February-2014 | 15 | 184 | 169 | 1.46 | 7.62 |
| | April-2014 | 15 | 190 | 175 | 1.49 | 7.59 |
| | June-2014 | 15 | 185 | 170 | 1.53 | 7.61 |
| | August-2014 | 15 | 184 | 169 | 1.52 | 7.59 |
| **S27** | September -2013 | 15 | 50 | 35 | 6.58 | 8.31 |
| | Nonmember -2013 | 15 | 191 | 35 | 6.74 | 8.29 |
| | Desember-2013 | 15 | 190 | 33 | 1.6.71 | 8.25 |
| | January -2014 | 15 | 186 | 38 | 6.74 | 8.12 |
| | February-2014 | 15 | 184 | 36 | 6.55 | 8.05 |
| | April-2014 | 15 | 190 | 35 | 6.61 | 8.12 |
| | June-2014 | 15 | 185 | 35 | 6.63 | 8.09 |
| | August-2014 | 15 | 184 | 34 | 6.54 | 8.13 |
| **S37** | September -2013 | 15 | 107 | 92 | 7.32 | 7.92 |
| | Nonmember -2013 | 15 | 103 | 88 | 7.40 | 7.83 |
| | Desember-2013 | 15 | 100 | 85 | 7.27 | 7.88 |
| | January -2014 | 15 | 95 | 80 | 7.30 | 7.75 |
| | February-2014 | 15 | 100 | 85 | 7.25 | 7.77 |
| | April-2014 | 15 | 105 | 90 | 7.36 | 7.86 |
| | June-2014 | 15 | 92 | 77 | 7.40 | 7.55 |
| | August-2014 | 15 | 95 | 80 | 7.35 | 7.61 |

**Table 6:** Groundwater depths and EC values for observation wells S6, S27 and S37.

1.4 to 8.29 dS/m, Table 6 shows measured groundwater depths and EC values for the observation wells S6, S27, and S 37. The groundwater quality was classified as medium saline water [1].

## Conclusions and Recommendations

The present research depicted that, to manage crop pattern and drainage water for sustainable cultivation the periodic monitoring for the quality of the irrigation water, drainage water, soil salinity, and groundwater are important issues for new land reclamation areas depending on low irrigation water quality (mixed freshwater with agricultural drainage water) and provided by irrigation and surface drainage networks. The analyzed results for irrigation and drainage water quality, soil salinity and groundwater for the Gelbana region (2500-hectare new reclaimed area since 2000) at the East South El-Qantara, North Sinai, Egypt concluded that irrigation water quality was slightly saline. The drainage water and groundwater were medium saline. Soil was classified as a poorly medium dense with EC varying from 1 to 4 dS/m, where the vertical drainage was low efficiency and insufficient to permit the washing of soil, especially in the low elevation areas. Soil salinity profiles in the root zone have been described that the filtration of salts is ineffective. It is recommended to (1) applying subsurface drainage (2) changing the cropping system in the plan according to the soil salinity levels measured (3) periodic monitoring for the irrigation water, drainage water, soil salinity, and the groundwater should be continued.

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