



Effect of Subsurface Drainage on Soil Properties and Yield of Maize Plant in Tina Plain Egypt

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Abstract

Agricultural drainage is critical for improving soil productivity and ensuring sustainable farming, particularly in irrigated regions. Effective drainage regulates excess water, maintains optimal moisture, enhances root development, and supports yield stability. In arid and semi-arid areas such as Egypt, inadequate drainage leads to waterlogging, salinity, and alkalinity buildup, which significantly reduce soil fertility and crop productivity. A field experiment was carried out at Tina plain region located at the southwest part of Sinai Peninsula (Latitude of 30°59'9.56"N and of longitude 32°26'59.60"E). This study aims to study the effect of subsurface drainage on soil properties and yield of Maize plants in Tina Plain of North Sinai, Egypt under low-quality irrigation water conditions. Soil samples were taken and analyzed before and after installing a tile drainage system with 40-meter spacing and a depth of 140 cm. The results showed that soil properties improved after installing the drainage system, organic matter increased, while soil salinity (EC), soil pH, and exchangeable sodium percent decreased. The installation of a subsurface drainage system resulted in an increase in plant height, seeds yield, N, P and K content and protein content of maize plant.

Keywords: Tina-Plain, Subsurface drainage, Soil properties, low water quality, Maize production.

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1. Introduction

Agricultural drainage is essential for sustainable agricultural land and so food productivity worldwide. In humid areas, drainage gives site traffic the ability to conveniently planting, harvest, and removes excess water from the root zone. In dry and semiarid areas, drainage is essential for waterlogging and salinity control. Despite the dramatic changes in cultivating rehearses and water resource deficiency, the structure models for the agriculture drainage system in Egypt have not been reviewed during the most recent three decades [1]. The Egyptian Public Authority for Drainage Projects (EPADP) mandate is to implement conduct the subsurface drainage system in Egypt. The current design criteria are mainly centered around controlling water-logging and soil salinity with minor contemplations for the subsurface drainage effect on water amount. The EPADP set the principles design criteria of the subsurface drainage system in Egypt to sustain land productivity and effective farming operations. [2] reasoned that around 8–14% of irrigation water was saved on account of controlling drainage in the winter months without a critical reduction in crop yield. Implementing control drainage can lead to a decrease in

drainage water. [3] structured an agricultural water management system to improve the crop yield and water quality by utilizing a procedure to control and lessening the drainage water and the related nitrate. [4] expressed that to decrease water irrigation quantities. A combination of the irrigation and drainage system should be worked out. Concentrating on controlling drainage in Egypt, particularly in the delta, uncounted inquiries were introduced. [5] derived that a large amount of drainage water was decreased to 68% in the summer season and 28% in the winter season as an immediate consequence of drainage control. A previous study [6] suggested that Egypt's agricultural drainage system should be changed to a controlled drainage system, which can significantly decrease the amount of irrigation water required for a given agricultural region. [7] demonstrated that the ideal strategy to control Egypt's drainage was the coordination between the gatherings concerned, including the official authorities and the farmers. Additionally, the examination guaranteed that for the example of applied shallow drainage, a noteworthy decrease in the necessary irrigation water amount was commented. Thus, a monetary decrease for actualizing a farming drainage system is going to be an

additive gain. A simulation study using DRAINMOD evaluated the hydrological and agronomic impacts of drain depths (100, 120, and 140 cm) at three Nile Delta sites (Zanklon, Tokh, Hosh Essa). Results indicated that reducing drain depth by 28.5% decreased irrigation water use by 15%, but also led to yield reductions (1.2–5.8%) depending on crop type and salinity levels. [1]. [8] assessed subsurface drainage impacts in four Pakistani projects (MSP, FDP, CCADP, MTDP). Post-drainage, crop yields improved by 13–94%, except at MTDP where rice yield declined by 23% due to inadequate irrigation. The most notable increases were observed in CCADP (cotton +80%, sugarcane +94%, wheat +67%). In MSP, rice yield rose by 46%, and in MTDP, chili yield increased by 147%. This study aims to investigate the effect of subsurface drainage on the physical and chemical properties of soil and the productivity of Maize plants in Tina Plain Egypt.

2. Materials and Methods

2.1. Study Area, Topography, Hydrogeology and Climate

The plain has a V-shaped configuration, bounded by the Mediterranean Sea (north and east), the Sinai Sand Sea (south), and the Suez Canal (west). The field area spans ~11.5 hectare, measuring 638.3 m (N–S) by 193.2 m (E–W). The source of irrigation in the region is Al-Salam Canal runs north–south across the field. This study aims to investigate the effect of subsurface drainage on the physical and chemical properties of soil and the productivity of Maize plants in Tina Plain Egypt. soil samples were collected before drainage installation in 2010 and again 12 years later in 2022. The study area lies at an elevation of 0.4 to 0.5 meters above sea level and features a flat terrain. Irrigation water for the Tina Plain is supplied by the El-Salam Canal Project, which crosses the Suez Canal via a siphon and extends eastward into northern Sinai’s desert. This project was designed to irrigate a total of 460,000 feddans, including: 92437 hectare west of the Suez Canal and 168067 hectare east of the canal in Sinai. The canal transports a total annual discharge of 4.45 billion m³, composed of 2.2 billion m³/year from Nile freshwater and 2.25 billion m³/year from the Bahr Hadous and Lower Serw drains. The water in the El-Salam Canal is a 50:50 mixture of freshwater and drainage water, maintaining an electrical conductivity (EC) below 1250 ppm, ensuring its suitability for irrigation. The annual averages of the irrigation water’s chemical composition for the winter and summer growing seasons of 2021/2022 are presented in Table 1. Samples were analyzed in the laboratory for the major ion chemistry employing standard method [9]. The southern part of the Tina Plain experiences a Mediterranean arid climate, characterized by hot, dry summers and cold winters with minimal rainfall. Temperature: In July, the maximum temperature reaches 31.3°C, while in January, it drops to a minimum of 4.9°C. Rainfall: The region receives an annual precipitation of only 33.3 mm, occurring exclusively in winter, with minimal runoff due to the low rainfall. Sunshine & Solar Radiation: The area enjoys an average of 8.3 sunshine hours per day, with solar radiation averaging 16.8 MJ/m² per day, creating favorable conditions for crop growth [10]. Drainage System, the main collector, is made of Polyvinyl Chloride (PVC), and was installed at a depth of 1.75 meters below the soil surface. The laterals were 75 meters long and spaced 40 meters apart, and installed at a depth of 150 cm. Each manhole connected with two laterals

(Fig. 2). Both the laterals and the collector had a slope of 0.1%. The diameter of the lateral pipes was 80 mm, while the main collector had a diameter of 200 mm. To support soil profile modeling, saturated hydraulic conductivity (K_s) was measured using undisturbed core samples from each plot. Samples were extracted at depths of 0–50 cm, 50–100 cm, and 100–150 cm. Following borehole drilling, aluminum rings of known dimensions were driven vertically and horizontally into the soil at each depth using a ring holder and hammer. The cores were secured in vibration-resistant containers and transported to the lab, where they were saturated and subjected to hydraulic overpressure for K_s determination (Figs. 1 and 2). Soil samples were taken from the surface layer for physical and chemical analyses and conducted in the laboratory of the Drainage Research Institute in Egypt. The soil was air dried for 6 days, crushed, sieved to pass through 2 mm plastic screen, thoroughly mixed and stored in plastic bags, Main soil properties are given in Table 2. Soil properties were determined according to [11].

2.2. Cultivated Crop

Maize (*Zea mays*) was cultivated over two cropping cycles in a 12-year field study: one prior to tile drainage installation in 2010 and another in 2022. Standard agronomic practices, including conventional tillage, pest control, and region-specific fertilization regimes, were applied. Nitrogen fertilizers (nitrate form) were applied in limited quantities post-emergence. Crop management included scheduled planting, harvesting, fertilization, and pre-harvest irrigation, followed by soil preparation for the next cycle. Drain outflow was monitored weekly to assess bypass activity, and effluent samples were collected once per growing season during active drainage for analysis. Wrapped tile drainpipes (with synthetic material) were installed in the field (mechanically) at spacing 40 -meter. Between late drains and 140 cm depth below soil surface. Soil samples were collected before drainage installation and after 12 years after that. Monitoring water table depth, and salinity changes. Measuring crop growth, root development, and yield improvements. Soil samples were collected both before the installation of the tile drainage system in 2010 and after its installation in 2022. Ten different samples were randomly collected from the field at a depth of 0-50 cm. The samples were air-dried, carefully crushed, and then prepared for routine chemical analysis.

2.3. Methods of analyses

2.3.1. Soil Analyses

Mechanical analysis: The particles size distribution of the soil samples was determined using the international pipette method as described by [12]. Electrical conductivity (EC, dS m⁻¹): The electrical conductivity (EC) of soil past extract was measured by electrical conductivity meter [13]. Total Calcium carbonate content of the soil was determined volumetrically using Collin's calcimeter described by [11]. Soil reaction (pH): was measured using glass electrode pH meter in soil paste [14]. Soluble cations and anions: Ca⁺⁺, Mg⁺⁺, K⁺, Na⁺, CO₃⁼, HCO₃⁻, Cl⁻ and SO₄⁼ (meq/L) [13]. Total organic matter was determined following Walkely and Black method, as described by [15]. Available N in soil: available N was extracted by 1.0M K₂SO₄ and determined by using the conventional method of micro-kjeldahl method according to [11]. Available phosphorus in soil: available phosphorus was determined

using [16], extracted with 0.5 M NaHCO₃ solution (pH 8.5) in presence of activated charcoal. Available K: was extracted with ammonium acetate (pH, 7) and determined using flame photometer instrument using method described by [11].

2.3.2. Plant Analyses

The total N pond K were determined in the wet digested as the following: Total nitrogen in plant was determined using the microkjeldahl method according to [17]. Total potassium in plant was determined by flame photometer according to [17]. Total phosphorus in plant was determined colourmetrically using ascorbic acid method [16].

2.4. Crop Production

Maize (a summer crop) are predominant in the region and selected for drainage evaluation. Specific areas within the experimental field (1 m²) were chosen both before and after the drainage installation. The weights of maize, the parameters of vegetative growth (plant height and leaves dry weight), ear (length and diameter) and harvest (grain and Stover yields) were measured, with results expressed as tons ha⁻¹. Protein percent "yield quality" in grains was calculated by multi plying N% × 5.70 [18].

3. Results and Discussion

3.1. Soil properties

3.1.1. Soil pH, organic matter (O.M.), EC, SAR and ESP values as affected by tile drainage and non-drainage.

Data of Table (3) and illustrated in Fig. (3) show that the values of soil pH, organic matter (O.M.), EC, SAR and ESP values as affected by tile drainage and non-drainage. The average pH value for soil before drainage was 8.53, whereas the average pH for the soil after drainage implementation was 7.47. The implementation of the tile drainage system notably reduced soil pH, especially on the upper layer of the soil profile. Highest value of soil pH was 8.56 while, lowest value was 7.46 after drainage. The implementation of tile drainage system notably reduced soil pH, especially on upper layer of soil profile. This reduction in pH is attributed to leaching of soil salts due to drainage system and organic matter content on upper soil layers compared to lower layers. These results are consistent with findings reported by [19]. Data in Table (3) & illustrated in Figs. (3) reveal that, Salinity levels, expressed as electrical conductivity (EC) of saturated soil paste extracts (dS m⁻¹), EC values ranged from 34.90 to 85.72 dSm⁻¹ Prior to drainage installation, while values ranged from 3.03 to 6.02 dSm⁻¹ after drain. The data clearly confirm that the soil under study exhibited extremely high salinity, likely due to high groundwater salinity in eastern north region [20].

However, following the installation of the drainage system, soil salinity profiles significantly decreased to acceptable levels below 3.0 ds/m within 12 years. This improvement can be attributed to the installation of tile drainage, which facilitated the removal of soluble salts that are leached from the root zone. Additionally, the enhancement in soil salinity conditions due to continuous cultivation, improved soil aggregation. These findings agreed with the results reported by [21]. Data in Table (3) and illustrated in Figs. (3) showed that Organic matter (OM) content ranged from 0.36 to 0.81%¹ Before drain, while values of OM ranged from 0.82 to 1.1 % after drain. Highest value of soil OM was 1.1%, while, lowest value was 0.36%. The highest OM concentrations were detected in surface

layers, attributed to crop residue accumulation from continuous cultivation. In undrained soils. Organic matter improves natural and chemical properties of soil, which is reflected in soil fertility and improves soil aeration and structure. According to [22], Addition of 10 t ha⁻¹ farmyard manure (FYM) mixed with chemical amendments significantly improved soil bulk density, total porosity, and hydraulic conductivity. Organic colloidal particles not only enhance soil structure but also modify solid-liquid interface by altering contact angle b/w soil particles and water [23].

As reported by [24] increased water retention in coarse soils treated with colloids is attributed to: (a) reduced bulk density and increased porosity, (b) improved soil structure and pore size distribution, (c) superior water-holding capacity of colloids compared to sand particles, and (d) decreased hydraulic conductivity due to structural modification. Organic amendments in sandy soils enhanced moisture retention, reduced bulk density, and increased porosity. Additionally, organic matter and compost served as nutrient sources, improving soil fertility. Recent findings [25] showed that compost mixed with chemical fertilizers further increased biomass and grain yields in rice and wheat. Data Table (3). indicated that the average sodium adsorption ratio (SAR) ranged from 24.52 to 57.22 before drain, while values of SAR ranged from 6.54 to 8.63 after drain. After the installation of tile drainage, SAR values decreased, ranging with mean 42.27 to 7.28. This reduction was most pronounced on the surface layers of the soil profiles. The decrease is likely due to the high leaching of sodium (Na⁺) relative to calcium (Ca⁺⁺) and magnesium (Mg⁺⁺). These findings are consistent with the results reported by [26]. Additionally, SAR values increased with soil depth, the trend is attributed to the downward movement and accumulation of soluble sodium that was drained from the surface layers.

[27] noted a strong positive correlation (0.76) between soil electrical conductivity (EC) and SAR before the installation of the tile drainage system, while the correlation coefficient between EC and SAR after installation was nearly zero (0.04). The percentages of exchangeable sodium (ESP) for all data are presented in Table (3). ESP) ranged from 29.41 to 68.34 before drain, while values of SAR ranged from 8.14 10.68 after drain. After the installation of tile drainage, SAR values decreased, ranging with mean 42.27 to 9.10. After installing the drainage system, ESP values decreased significantly. A positive correlation with $r = 0.85$ was observed between electrical conductivity of soil (EC) and ESP before the installation of the tile drainage system. However, after installation, there was no significant correlation between EC and ESP. The reduction in ESP following the construction of tile drainage is attributed to increased leaching of Na⁺ ions, which in turn leads to a decrease in SAR. These results are consistent with those reported by [28]. Additionally, ESP values increased with soil depth under all studied conditions. This rise is because of the higher solubility of sodium salts, which move downward more readily with leaching process and irrigation water in contrast to calcium and magnesium salts [29].

3.1.2. Soil Texture and Soil Hydraulic Conductivity

The data indicated illustrates the particle size distribution in the studied soil profiles, with a summary of these values (by soil depth) before and after drainage installation of drainage system. The data reveal that the soil predominantly falls into the sandy loam categories. Table 4,

Before tile drainage system installation its observed that, sand, silt, and clay percentages ranged from 71.07% to 74.12% (average 71.55%), 20.07% to 24.21% (average 23.44%), and 4.36% to 5.81% (average 5.01%), respectively. For after drains, the ranges are 66.42% to 70.73% (average 70.73% sand), 13.71% to 17.92% (average 13.83% silt), and 16.76% to 18.63% (average 15.44% clay). Additionally, it was observed that clay content slightly increased with depth after drainage installation. This clay particle migration due to the installation process where drainage machine mixes the upper soil texture with the lower soil profile and also the moving of fine particles due to leaching through continuous irrigation of agricultural lands during the study. The relatively coarse texture within the soil is linked to a low ability to retain moisture, making it crucial to manage water use efficiently for plant growth. Predominance of drainable pores, i.e. macro- and meso- soil porosity, and siliceous characteristics within soil, dominated by sand, assist in limited capacity for retaining sufficient moisture for plants. Further details are available in Table 4. Soil textural classes in the studied profiles remained unchanged before and after installation of tile drainage system. Coarse texture observed is entirely influenced by parent material and geological formation [29].

Hydraulic conductivity (Ks) values for the studied soil profiles are presented in Table 5. Ks consistently increased after tile drainage installation across all profiles, attributed to trench excavation causing soil restructuring, enhancing aggregate formation, pore space, and water pathways. Pre-installation, Ks ranged up 31 to 0.46 m/day with a mean of 0.38 m/day (standard deviation = 0.052), while post-installation values ranged from 0.66 to 1.29 m/day, with a mean of 0.83 m/day (standard deviation = 0.19). Hydraulic conductivity depends on pore geometry, particle surface characteristics, and factors such as soil texture, structure, density, degree of cementation, organic matter content, and the presence of Ca^{++} or Na^+ ions, as well as the type of clay minerals [30]. The design and performance of tile drainage systems are heavily dependent on soil's saturated hydraulic conductivity (K), [31], where this parameter is employed in all drain-spacing equations. Consequently, accurately determining of the K-value is critical when designing or assessing a drainage project. It can be concluded that the tile drainage system implemented in the experimental field effectively lowers the water table depth and enhances soil hydrological properties. This improvement is reflected in increased water table draw-down rates, greater drainage intensity, and higher soil hydraulic conductivity. Maintaining nutrient balance for long-term agricultural use.

3.2. Crop Yield

3.2.1. Maize growth, yield as affected by the drainage system

Seed germination percentage, growth parameters (plant height, leaf dry weight), maize ear traits (length, diameter), and biological yield (grain and stover) of representative maize plants summarized in Table 6. Results indicate that all measured parameters from 2010 to 2022 in fields irrigated with El-Salam canal water under drainage showed significantly higher values post-tile drainage installation compared to pre-installation. Statistical analysis (L.S.D., $p < 0.05$) confirmed significant improvements in maize growth and yield parameters following drainage implementation across all studied seasons. Table 6 shows that

post-drainage maize harvest parameters were grain yield of 2.18 and stalk dry weight of 2.573 ton/fed, compared to 0.54 and 0.673 ton/fed, respectively, before drainage. These results align with studies. [32-33] indicating that moderate soil moisture stress allows deeper root water extraction and more efficient water use, whereas excessive soil moisture depletion reduces water use efficiency. A gradual, significant increase in all studied plant parameters was observed from 2010 to 2022, coinciding with a progressive decrease in soil salinity and sodicity over the cultivation period. The benefits of the drainage system include reducing nutrient dilution and minimizing losses of available water and nutrients beyond effective root zone. Conversely, prior to drainage installation, plant performance was constrained by soil moisture stress and imbalanced soil water-air relations, which suppressed photosynthesis and disrupted hormonal and physiological processes, negatively affecting vegetative growth, dry matter accumulation, and causing flower defoliation [30].

Post-drainage improvements are attributed to enhanced soil water-air balance, promoting nutrient uptake and sustaining soil fertility, thereby providing optimal conditions for seed germination and root development [31]. Table 6 shows that post-drainage maize harvest parameters were grain yield of 2.18 ton/fed and stalk dry weight of 2573.71 kg/fed, compared to 0.54 ton/fed and 673.19 kg/fed, respectively, before drainage. These results align with the studies [32-33] indicating that moderate soil moisture stress allows deeper root water extraction and more efficient water use, whereas excessive soil moisture depletion reduces water use efficiency. In summary, increase in maize harvest parameters closely paralleled corresponding vegetative growth values (Table 6). Post-drainage vegetative and ear parameters were: germination 82.08%, plant height 179.44 cm, leaf dry weight 67.27 g/plant, ear length 17.64 cm, and diameter 4.44 cm. Before drainage, these values were significantly lower: germination 16.05%, plant height 32.4 cm, leaf dry weight 16.61 g/plant, ear length 5.18 cm, and diameter 1.28 cm. This response magnitude likely depends on drainage system type and associated soil moisture stress, as plots with drainage consistently showed the higher values compared to those without.

These results align with [34], who attributed maize yield declines mainly to reduced soil moisture availability limiting water and nutrient uptake. Additionally, [35-36] reported that tile drainage effectively lowers root-zone salinity, enhances crop yield, and reduces waterlogging. Similar findings were reported by [2], who observed a 6.9% increase in crop yield due to drainage, attributed to improved soil water content in root zone by maintaining an optimal water table depth. [37] documented enhanced maize and soybean yields with drainage in a two-year field study in eastern Ontario, while [38] reported a 64% maize yield increase under drained conditions. Likewise, [39] found that a water table at 0.70 m improved moisture availability in root zone, enhancing water and mineral uptake and increasing alfalfa dry matter yield. Conversely, [40] noted yield declines at 1.2 m water table depth, likely due to reduced available water and nutrient leaching-induced low soil fertility. Maize, being highly responsive to irrigation volume, showed increased dry weight with higher water levels, reflecting improved rhizosphere moisture that enhances photosynthesis, cell division, stem elongation, and biomass accumulation.

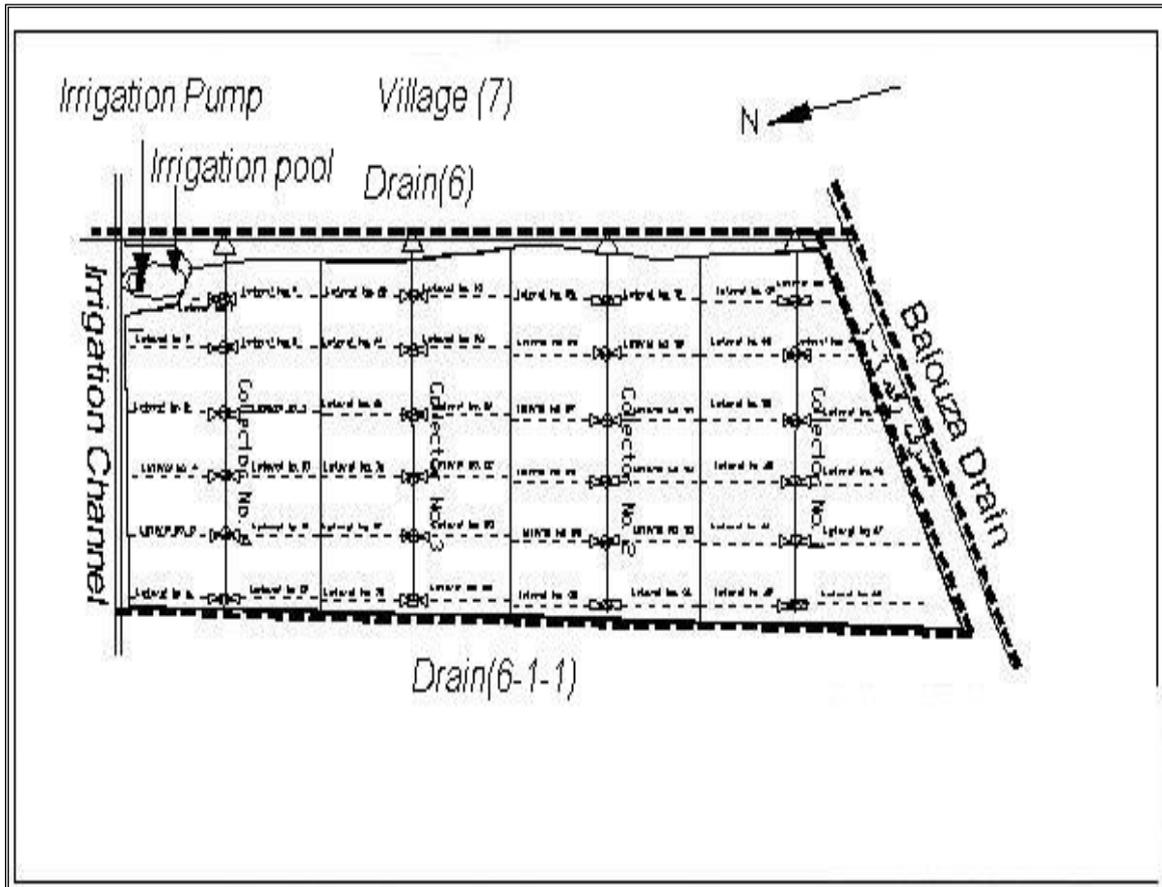


Fig. 1: Drainage network in the area under study.



Fig. 2. Tina plain, Egypt

Table 1: Certain chemical properties of irrigation water from the El-Salam Canal

Properties	Value
EC, dS/m	1.55
EC, ppm	995
Ph	7.75
Soluble and Cations and Anions, mmole/L	
Ca ⁺²	3.62
Mg ⁺²	2.65
Na ⁺	9.02
K ⁺	0.21
Cl ⁻	6.53
CO ₃ ⁻	0.0
HCO ₃ ⁻	5.21
SO ₄ ⁻²	3.76
Salinity	C3, High
BOD (mg/l)	9.41
Quality parameters of water	
NH ₄ ⁺ N, mg L ⁻¹	2.02
NO ₃ -N, mg L ⁻¹	1.49
Fe, mg L ⁻¹	0.02
Zn, mg L ⁻¹	0.04
B, mg L ⁻¹	0.11
Pb, mg L ⁻¹	0.03
Ni, mg L ⁻¹	0.03
SSP,%	58.19
SAR	5.09
RSC	-1.06
USDA Class	C3S1

Note: **SAR:** Sodium Adsorption Ratio (SAR ≥ 10: Low for sodium); **SSP:** Soluble sodium percentage (SSP ≥60%: Low for soluble sodium); **RSC:** Residual Sodium Carbonate (RSC ≥1.25: Moderate for irrigation)

Table 2: Means of Some physical and chemical properties before study

Soil characteristics	Value
Soil particles distribution	
Sand ,%	72.25
Silt,%	22.73
Clay,%	5.02
Textural class	Sandy Loam
Field capacity (FC),%	15.43
CaCO ₃ , (%)	3.55
Organic matter,(%)	0.48
pH*	8.53
EC,(dSm ⁻¹) **	59.7
Soluble cations and anions, (mmolc L⁻¹)**	
Ca ⁺⁺	150
Mg ⁺⁺	116
Na ⁺	297
K ⁺	34.78
CO ₃ ⁼	0.00
HCO ₃ ⁻	175
Cl ⁻	208
SO ₄ ⁼	214
Available nutrients (mg kg⁻¹soil)	
Available N	28.67
Available P	11.04
Available K	108

* Suspension of 1:2.5 soil:water

** Soil paste extract

Table 3: Mean of soil pH, organic matter (O.M.), EC, SAR and ESP values as affected by tile drainage and non-drainage

Location	pH		O.M,%		EC (dSm ⁻¹)		SAR		ESP,%	
	Before drain	After drain	Before Drain	After drain.	Before drain.	After drain.	Before drain.	After drain.	Before drain.	After drain.
1	8.52	7.59	0.36	0.82	40.72	4.47	28.91	6.54	34.67	8.14
2	8.55	7.46	0.56	0.91	52.51	4.25	38.07	6.62	45.46	8.37
3	8.50	7.92	0.47	0.92	34.90	6.02	24.52	7.54	29.41	9.36
4	8.53	7.91	0.65	1.0	60.44	4.57	40.86	7.46	48.82	9.24
5	8.52	7.85	0.81	1.0	85.72	3.03	57.22	7.31	68.34	9.19
6	8.51	7.79	0.54	0.92	52.52	4.27	38.02	6.68	45.45	8.36
7	8.56	7.48	0.47	0.90	64.33	4.12	47.13	6.75	56.18	8.58
8	8.54	8.02	0.48	0.92	69.71	3.92	49.03	7.44	58.45	9.34
9	8.53	7.93	0.78	1.0	66.45	4.72	47.24	7.82	56.20	9.76
10	8.55	7.78	0.74	1.1	69.37	5.83	51.72	8.63	61.52	10.68
Mean	8.53	7.77	0.58	0.95	59.67	4.52	42.27	7.28	50.45	9.10

Note: O.M.: organic matter, SAR: sodium adsorption ratio, ESP: exchangeable sodium preents

Table 4: Weight mean of particle size distribution values before and after drainage Installation

Location	Before tile drainage				After tile drainage			
	Sand,%	Silt,%	Clay,%	Soil Texture	Sand,%	Silt,%	Clay,%	Soil Texture
1	74.12	20.07	5.81	Sandy Loam	66.42	15.81	17.77	Sandy Loam
2	73.51	21.72	4.77	Sandy Loam	67.44	14.83	17.73	Sandy Loam
3	71.43	24.21	4.36	Sandy Loam	67.66	13.71	18.63	Sandy Loam
4	71.07	23.60	5.33	Sandy Loam	67.82	14.85	17.33	Sandy Loam
5	72.02	23.21	4.77	Sandy Loam	68.09	15.90	16.01	Sandy Loam
6	71.83	23.04	5.13	Sandy Loam	68.07	13.75	18.18	Sandy Loam
7	72.24	22.73	5.03	Sandy Loam	68.43	13.71	17.86	Sandy Loam
8	73.75	21.56	4.69	Sandy Loam	64.48	17.92	17.6	Sandy Loam
9	72.32	22.90	4.78	Sandy Loam	67.71	15.53	16.76	Sandy Loam
10	71.55	23.44	5.01	Sandy Loam	70.73	13.83	15.44	Sandy Loam
Mean	72.38	22.65	4.97	Sandy Loam	67.69	14.98	17.33	Sandy Loam

Table 5: Average Soil hydraulic conductivity before and after tile drainage installation

Profile	Hydraulic conduct. (m/day)	
	Before drainage	After drainage
1	0.36	0.72
2	0.40	0.81
3	0.31	0.67
4	0.39	0.98
5	0.46	1.29
6	0.40	0.79
7	0.44	0.90
8	0.37	0.71
9	0.36	0.78
10	0.31	0.66
Mean	0.38	0.83

Table 6: Average Germination percentage, vegetative and harvest parameters of maize as affected before and after drainage system

Drainage system (DS)	Germination %	Vegetative growth parameters		Maize ear parameters		Harvest parameters	
		Plant height (cm)	Leaves dry weight / plant (g)	Length (cm)	Diameter (cm)	Grain yield (ton/fed)	Dry weight of maize stalk (ton/fed)
Before drainage	16.05	32.43	16.61	5.18	1.28	0.54	0.673
After drainage	82.08	179.4	67.27	17.64	4.44	2.18	2.57

Table 7: Average nitrogen, phosphors, potassium and protein content of maize plants as affected before and after drainage system

Drainage system (DS)	Chlorophyll a, mg g ⁻¹ f wt	Chlorophyll b, mg g ⁻¹ f wt	Carotenoids, mg g ⁻¹ f wt	N,%	P,%	K,%	Protein content.%
Before drainage	1.56	0.48	0.57	1.67	0.28	1.71	9.74
After drainage	1.97	0.89	0.86	2.25	0.51	2.43	13.85

[41] reported significant annual maize yield variability influenced by climate, with drained and controlled drainage systems achieving highest yields (up to 14.5 t ha⁻¹ grain), representing average increases of 27.3% in grain maize and 4.0% in silage maize.

3.2.2. NPK and protein content of maize as affected by the drainage system

Table 7 showed that the effect of drainage system on Chlorophyll a, Chlorophyll b, Carotenoids (mg g⁻¹f wt), nitrogen, phosphors, potassium and protein content of maize plants. Value of Chlorophyll a, Chlorophyll b, Carotenoids (mg g⁻¹f wt) ranged from 1.56, 0.48 and .67 mg g⁻¹f wt, respectively before drainage, while value ranged from 1.97, 0.89 and 0.86 mg g⁻¹f wt after drainage. Value of N, P, K and content ranged from 1.67, 0.28, 1.71 and 9.74%, respectively before drainage and ranged from 2.25, 0.51, 2.43 and 13.85%, respectively after drainage. Data showed that maize yields under tile drainage systems are higher than in non-drained soils, showing a 76% increase in corn yield. This improvement is attributed to tile drainage’s enhancement of soil properties, including maintaining optimal air-water balance and thermal conditions, which promote biological activity and nutrient availability. The system also mitigates soil salinity and alkalinity effects. Moreover, tile drainage conserves land otherwise used for open canals, enabling increased cultivation area and improved soil productivity [42]. These findings align with [41] demonstrating that tile drainage enhances yields in crops such as corn and forages [43-44]. For example, [45] reported a 46.77% yield increase in corn. Additionally, tile drainage improves machinery efficiency on drier soils, reducing labor hours [45-46] and lowering fossil fuel use and associated costs [47].

4. Conclusions

Subsurface drainage significantly improves soil conditions and crop productivity. Essential for sustainable agriculture in saline-prone regions like Sinai. The Subsurface Drainage System is notably effective in creating a lower water table, reducing salinization and alkalization, and improving soil water, air, and heat conditions. These improvements lead to better soil conditions that boost biological activity and maintain nutritional balance by protecting the soil from the detrimental consequences of salinity and alkalinity. Additionally, it conserves land that would otherwise be used for constructing surface canals. Compared to non-drained soils, this system significantly lowers salt concentrations. It also helps retain water in the subsurface layer, promoting better plant growth. Implementing a System of Subsurface Drainage on a farm scale in the southwest part of the Tina plain region can be beneficial, especially in conserving low-quality irrigation water. The effectiveness of a drainage system depends on local site characteristics, including soil characteristics, land

slope, climate, cropping practices, nutrient management, and the keep of the system of drainage itself. Over next 20 years, water conservation will become increasingly crucial due to constraints from fixed Nile water share, rising population, industrial growth, and horizontal expansion plans.

Enhancing the efficiency of arable land is essential for sustainable development. Effective drainage techniques are used to improve soil quality and support sustainable farming practices while preserving agricultural yields, managing soil and water resources, and controlling farmer costs. Subsurface drainage can effectively address issues of high groundwater levels and soil salinity, while boosting crop yields in semi-arid regions. In the context of maize, it was observed that crops grown and irrigated with a subsurface drainage system were benefitted from optimal management practices, resulting in the highest productivity per unit area. Additionally, this approach contributed to improved grain quality for both maize. Low-quality water (non-conventional water) is recommended for use in leaching, saline soils. During the leaching process, soil amendments must be applied to prevent soil from deteriorating to alkalinity. Monitoring soil EC and pH are essential during the leaching process. Installing subsurface drainage after soil reclamation is important to remove excess water from soil profile. Design criteria for newly reclaimed areas must be carefully studied, especially in regions using modern irrigation systems. Leaching is a vital process for reclaiming saline and alkaline soils, such as the Tina Plain. Further research on optimizing drainage system design.

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