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CHANGE DETECTION OF SOIL HYDROPHYSICAL PROPERTIES AND CHARACTERISTICS OF TINA PLAIN, SINAI, EGYPT UNDER SUBSURFACE DRAINAGE SYSTEM

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ABSTRACT

This study assesses the impact of subsurface drainage on agricultural productivity in the Tina Plain, Sinai, Egypt in pilot area covering 27.36 feddans of sandy-textured soil irrigated with low-quality water. A subsurface pipe drainage system was installed with lateral spacing of 40 meters and a depth of 140 centimeters to enhance soil and water management. The system effectively reduced the water table, improved soil aeration and water infiltration, and significantly mitigated soil salinity and alkalinity issues. These improvements fostered a more favorable soil environment, boosting biological activity and preserving nutrient balance. Furthermore, the drainage system reduced reliance on surface drainage canals, thereby increasing the cultivable land area. The results underscore the importance of subsurface drainage in promoting agricultural sustainability, resource efficiency, and improved land use in arid and semi-arid regions. In summary, subsurface drainage not only improves soil and crop performance but also supports long-term agricultural development in marginal environment.

Keywords: Subsurface drainage; soil improvement; Tina Plain; soil physical properties

INTRODUCTION.

Egypt's national development is inextricably linked to the strategic utilization of its land and natural resources, which serve as primary drivers of economic growth and sustainability. The country possesses significant natural endowments, including fertile soils within the Nile Valley and Delta, abundant water resources from the Nile River, underground aquifers, the reuse of agricultural drainage water, treated wastewater, and seawater desalination. Despite these advantages, extensive areas, particularly in desert and coastal regions, remain underutilized. Expanding agricultural, industrial, and urban activities into these regions necessitates advancements in infrastructure, sustainable water management, and innovative land reclamation techniques. Maximizing the efficient use of these resources is crucial for ensuring Egypt's economic stability and long-term sustainability (**MWRI, 2020; FAO, 2017).**

Limited freshwater availability, heavy reliance on the Nile River, and variability in groundwater quality present significant barriers to sustainable agricultural expansion. Furthermore, issues of soil salinity and alkalinity, exacerbated by prolonged irrigation without adequate drainage, threaten soil fertility and crop productivity. Addressing these challenges requires the adoption of effective drainage systems to regulate water tables, mitigate waterlogging, and enhance soil health. The integration of modern drainage technologies with sustainable land management practices is critical for optimizing land productivity, enhancing food security, and supporting Egypt's agricultural sustainability objectives (**MWRI, 2020; FAO, 2017).**

In this context, Egypt's efforts to optimize agricultural productivity through improved drainage are especially pertinent. To evaluate the impact of varying drainage depths on crop performance, three experimental sites—Zanklon Tokh, and Hosh Essa—were established in the Nile Delta. Utilizing the DRAINMOD numerical model project, researchers simulated hydrological conditions, crop yields, and soil salinity under drainage depths of 140 cm, 120 cm, and 100 cm. Results indicated that reducing drainage depth by 28.5% led to a 15% reduction in irrigation water use. However, crop yields experienced declines ranging from 1.2% to 5.8%, depending on crop type and prevailing soil salinity levels **(Eid *et al.*, 2021).**

Overall, subsurface drainage can achieve up to 80% reduction in topsoil salt content **(Han *et al.*, 2023),** significantly enhancing crop performance. Long-term impacts of drainage on agricultural productivity have also been explored. A 37-year study conducted by **Rui *et al.* (2024)** in southeastern Indiana assessed the effects of drainage spacing (5 m, 10 m, and 20 m) compared to undrained control fields. Results indicated that drainage contributed to 12%–17% increases in corn (*Zea mays*) yields, while soybean (Glycine max) yields remained relatively stable. Benefits of drainage became more pronounced over time, especially when coupled with conservation practices such as no-till farming and cover cropping. In contrast, yields in undrained fields remained stagnant. Excessive rainfall during the critical 14-day post-planting period was identified as a major factor influencing yield variability, with drainage systems effectively mitigating its adverse effects. These findings underscore the pivotal role of subsurface drainage in supporting conservation agriculture and enhancing resilience to climatic variability.

Recent advancements have also highlighted the value of integrating data-driven approaches in surface drainage planning. **(Sagar *et al.*, 2024)** evaluated the impact of a data-driven surface drainage strategy implemented on a commercial row-crop farm. By leveraging field topography, drainage characteristics, and historical yield data, researchers optimized drainage improvements beyond conventional methods. Following implementation, corn yields increased by 18.3% and 13.9% across two fields, while specific areas directly benefiting from enhanced drainage recorded even greater gains15.9%–26.5% in one field and 21.4%–40.2% in another. Similar improvements were observed for soybean yields. These findings highlight the transformative potential of precision surface drainage planning and the benefits of data-informed decision-making for agricultural productivity.

Collectively, these studies demonstrate the critical importance of both subsurface and surface drainage systems in optimizing water management, improving soil health, and boosting agricultural yields. Future research should prioritize the refinement of drainage technologies, the integration of climate-adaptive management strategies, and the development of smart, sustainable approaches to further strengthen agricultural resilience in regions grappling with water scarcity and soil degradation. Therefore, the objectives of the study were to a) assess the role of subsurface drainage in enhancing soil properties and b) evaluate the changes in soil

MATERIALS AND METHODS

Study area and methodology

The pilot area under study is located within the Tina Plain in northern Sinai, encompassing a total area of 27.36 feddans. It is positioned at latitude 30° 59' N and longitude 32° 26' 55" E. The Tina Plain exhibits a distinctive V-shaped configuration and is geographically bounded by:

- The Mediterranean Sea to the north,
- The northern Sinai Sand Sea to the south,
- The Suez Canal to the west, and
- The Mediterranean Sea to the east **(Figure 1).**

The study area, located in the northern part of the Sinai Peninsula, holds considerable strategic importance for Egypt's national development. The Sinai Peninsula is endowed with vast yet largely underutilized natural resources, including fertile soils, water resources, valuable mineral deposits, and a critical geographical location linking Africa and Asia. In terms of land cover, the study area comprises a mosaic of vegetated and non-vegetated zones. Vegetated areas include both artificially irrigated and rain-fed agricultural lands, while non-vegetated areas consist of barren lands and water bodies. Cultivated crops in the region encompass terrestrial tree crops, terrestrial herbaceous crops, and aquatic herbaceous crops, reflecting the diversity of agricultural activities supported under the prevailing environmental conditions.

Climate and hydrology

The southern part of the Tina Plain is characterized by a Mediterranean arid climate, distinguished by hot, dry summers and cool winters with minimal rainfall. Key climatic features include: Temperature: Average maximum temperatures peak at 31.3°C in July, while minimum temperatures drop to 4.9°C in January.

Rainfall

The region receives an annual precipitation of only 33.3 mm, concentrated exclusively during the winter months. Due to the low volume of rainfall, surface runoff is minimal.

Sunshine and solar radiation

The area enjoys an average of 8.3 hours of sunshine per day. Solar radiation levels reach approximately 16.8 MJ/m² per day, providing favorable conditions for agricultural production **(Gabr and Fattouh, 2020).** These climatic and hydrological characteristics present both challenges and opportunities for agricultural development in the Tina Plain, emphasizing the need for efficient water management and resilient cropping systems.

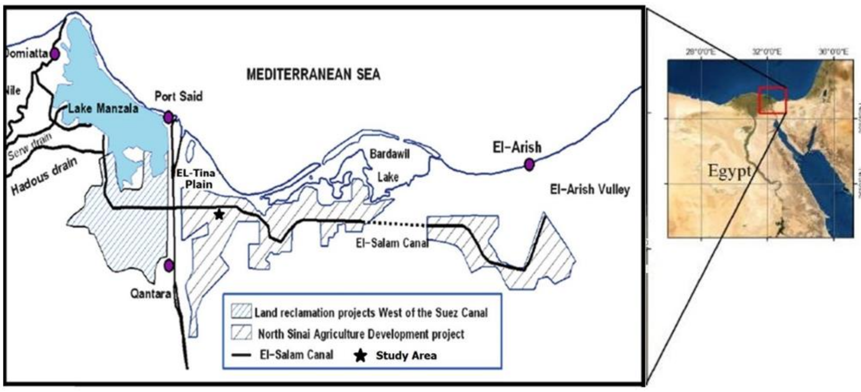

Figure (1): The site of the pilot area under study **(Kaiser, 2009).**

Irrigation System at El-Salam Canal

The Tina Plain is irrigated through the El-Salam Canal Project, which extends eastward into the northern Sinai desert after crossing the Suez Canal via a siphon. The canal delivers an annual water discharge of 4.45 billion m³, sourced from as follows: 2.2 billion m³/year of Nile freshwater. 2.25 billion m³/year from the Bahr Hadous and Lower Serw drains.

The water supplied through the El-Salam Canal is a 50:50 blend 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 and 2022/2023 are presented in **Table 1 and Figure 1.**

Location

Tina Plain, North Sinai. Area: 27.36 feddans. Bordered by drain No. 6 and Village No. 7 to the east **(Figure 2),** and irrigated by El-Salam Canal.

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

Properties	2021/2022		2022/2023		Annual averages	
	Winter	Summer	Winter	Summer	Winter	Summer
Temprature	21.37	25.63	18.06	24.88	19.72	25.63
pH	7.87	7.73	7.68	7.71	7.77	7.73
EC (dS/m)	1.82	1.49	1.49	1.32	1.66	1.49
Ca^{++}(meq\l)	4.21	3.46	3.38	3.15	3.79	3.46
Mg^{++}(meq\l)	2.91	2.45	2.67	2.30	2.79	2.45
Na^{+}(meq\l)	10.46	8.57	8.48	7.24	9.47	8.57
K^{+}(meq\l)	0.46	0.37	0.34	0.42	0.40	0.37
CO_3 (meq\l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3 (meq\l)	5.07	5.34	5.23	4.83	5.15	5.34
Cl (meq\l)	8.40	6.10	5.95	5.12	7.17	6.10
SO_4_m (meq\l)	3.77	2.92	3.12	2.76	3.45	2.92
SO_4_Cala(meq\l)	4.56	3.42	3.67	3.17	4.12	3.42
Coliform (CFU/100ml)	24066.7	5400.0	2233.3	3000.0	13150.0	5400.0
Fecal (CFU/100ml)	3140.0	1780.0	108.3	1013.5	1624.2	1780.0
BOD (mg/l)	11.50	9.25	7.60	12.67	9.55	9.25
TSS (mg/l)	35.71	17.57	30.00	32.67	32.86	17.57
NO_3 (mg/l)	2.31	1.18	1.09	1.75	1.70	1.18
NH_4 (mg/l)	2.75	1.61	2.13	0.66	2.44	1.61
TP (mg/l)	1.19	0.78	0.44	0.44	0.82	0.78
Cu (mg/l)	0.05	0.07	0.04	0.03	0.04	0.07
Fe (mg/l)	0.02	0.02	0.04	0.02	0.03	0.02
Zn (mg/l)	0.01	0.02	0.11	0.01	0.06	0.02
Ni (mg/l)	0.00	0.03	0.00	0.02	0.00	0.03
Pb (mg/l)	0.02	0.03	0.04	0.00	0.03	0.03
TDS_Lab (mg/l)	1166.29	992.67	988.38	883.02	1077.34	992.67
SAR	5.50	4.96	4.89	4.34	5.19	4.96
Adj_SAR	6.65	5.97	5.80	5.12	6.22	5.97
RSC	0.02	0.03	0.00	0.00	0.01	0.03

Source: National Water Research Center (NWRC), Ministry of Water Resources and Irrigation (2023)

Subsurface draining system description

The drainage system was installed at a depth of 1.40 meters below the soil surface, with lateral drains spaced at 40-meter intervals.

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The design parameters for the study area are illustrated in **Figure 2**. The impermeable layer was located at a depth of 4.0 meters from the soil surface, and the drainage coefficient was determined as 1.0 mm/day. Prior to the installation of the drainage system, the initial depth of the water table was measured at 1.10 meters.

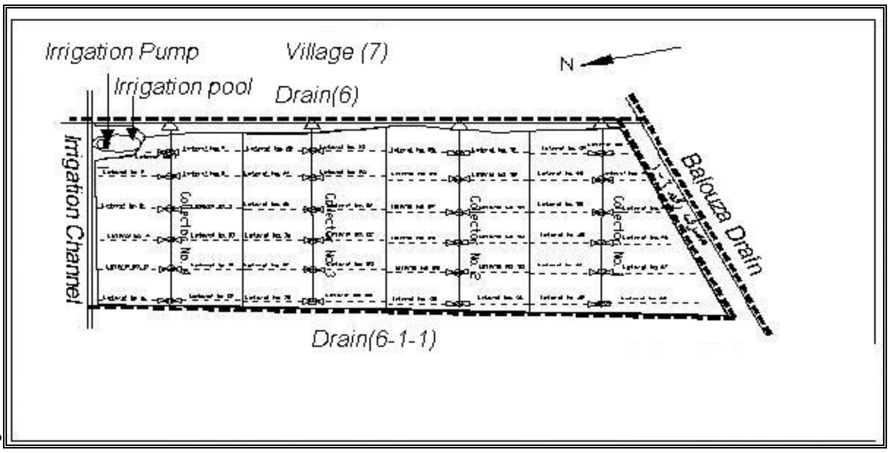

Figure 2: Drainage network in the area under study.

Data collection and analysis

Soil sampling before and after drainage installation (12-year study) was collected**.** Also, soil physical properties were monitored during the same period. Along with monitoring water table levels trends for the same period.

Field measurement

Ground water table depth was measured daily between two consecutive irrigation intervals using a measuring tap connected to a sounder **(Ritzema, 1994).** Hydraulic conductivity (K) was measured in the field using the auger hole method, as described by **Van Beers (1965).** The hole had a depth of 160 cm from the soil surface and a diameter of 20 cm.

Laboratory measurements

Soil samples

Disturbed soil sampling for determining soil texture

Soil samples were collected for texture determination. A total of 15 soil profiles were excavated to a depth of 150 cm, with samples taken at three depth intervals: 0-50 cm, 50-100 cm, and 100-150 cm. The samples were then air-dried, carefully crushed, and prepared for texture analysis.

Undisturbed soil sampling for physical analysis

Soil moisture retention curves were determined using undisturbed soil cores (2.5 cm height) **(Topp *et al.,* 1993).** Field capacity and the permanent wilting point were established using a pressure plate apparatus, with moisture content expressed on a dry weight basis (W) and adjusted for bulk density **(Klute, 1986).**

Available water content was calculated as the difference between soil moisture at field capacity and the permanent wilting point. Bulk density was measured using soil samples collected in metallic cylinders (98 cm³ volume) according to the method described by **Vomocil (1957).** Infiltration rate was measured using the double-ring infiltrometer method

RESULTS AND DISCUSSION

Soil texture

Figure (3) illustrates the particle size distribution in the studied soil profiles, with a summary of these values (by soil depth). The data reveal that the soil predominantly falls into the sandy or sandy loam categories. The percentages of sandy, silt, and clay particles at different depths are as follows: 0-50 cm (65.9%, 18.4%, and 15.7%), 50-100 cm (68.9%, 15.4%, and 15.7%), and 100-150 cm (72.5%,

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13.3%, and 14.2%). In contrast, for the non-wrapped pipe drains with synthetic envelope, the particle distribution is: 0-50 cm (74.5% sand, 21.6% silt, and 4.0% clay), 50-100 cm (73.9% sand, 20.7% silt, and 5.4% clay), and 100-150 cm (75.7% sand, 18.2% silt, and 6.1% clay). Previous data indicate that sandy loam or sandy textural classes are predominant, as compiled within **Figure 5.**

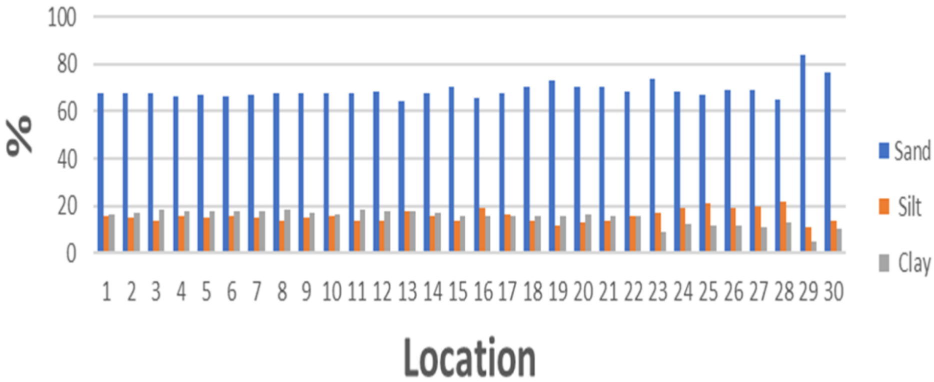

Figure (3). Soil texture for the area under study.

Soil properties improvements

The installation of the tile drainage system also contributed to significant enhancements in soil physical properties, including improving soil aeration, improving water retention and, reducing risks of soil salinity and alkalinity.

Soil hydraulic conductivity (K)

The soil hydraulic conductivity (K)values, presented in **Figure 4** revealed a notable increase in K after the installation of the tile drainage system compared to pre-drainage conditions. This improvement is primarily attributed to the removal of water from soil due to drainage installation, which enhanced soil structure by increasing soil aggregation, pore space, and the continuity of water pathways.

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Comparison of hydraulic conductivity before and after drainage installation

Before drainage

Maximum value of hydraulic conductivity was: 0.46 m/day, mean hydraulic conductivity was: 0.38 m/day (standard deviation: 0.052).

After drainage

Hydraulic conductivity ranged between 0.65 and 1.29 m/day and mean hydraulic conductivity: 0.86 m/day (standard deviation: 0.22). The increase in soil hydraulic conductivity after drainage installation underscores the system's effectiveness in promoting water movement, improving drainage efficiency, and mitigating waterlogging risks.

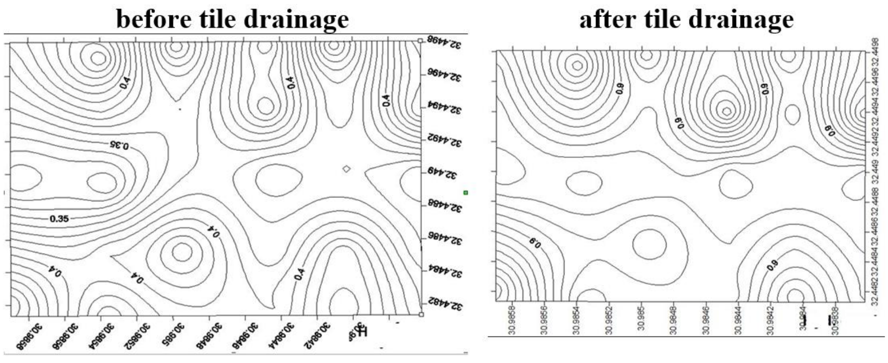

Figure 4: Soil hydraulic conductivity before and after subsurface pipe drainage system installation.

Bulk density of soil

Bulk density is an indicator of soil compaction and porosity, influencing water infiltration, root growth, and soil aeration. The results, detailed in **Figure 5** highlighted the positive effects of tile drainage on bulk density across different soil depths.

Bulk density before and after subsurface pipe drainage system installation.

Before drainage

At 0–50 cm depth, the bulk density appeared 1.49 g/cm³, while at 50–100 cm depth, the bulk density was 1.53 g/cm³, and at 100–150 cm depth, it was 1.55 g/cm³

After drainage

At 0–50 cm depth, the bulk density was 1.33 g/cm³, 50–100 cm depth, it was 1.39 g/cm³, and at 100–150 cm depth, it 1.41 g/cm³. Across all depths, bulk density values declined significantly after drainage installation, indicating improved soil structure and porosity. Collectively, before the drainage the bulk density values ranged from 1.51 to 1.54 g/cm³ with an overall mean and standard deviation of 1.52±0.02 g/cm³. while after the drainage the values were decreased to between 1.35 and 1.43 g/cm³ with a mean of 1.38±0.03 g/cm³.

Factors influencing bulk density variations

Soil depth and natural compaction:

Bulk density naturally increased with depth due to overburden pressure.This trend was consistently observed across all profiles **(Figure 7).**

Impact of tile drainage on soil structure

Bulk density reductions can be attributed to:Enhanced soil aeration and restructuring from excavation and improved water movement. The formation of macro-pores, which reduced compaction and improved water and air movement within the soil profile.

before pipe drainage installation **after pipe drainage installation**

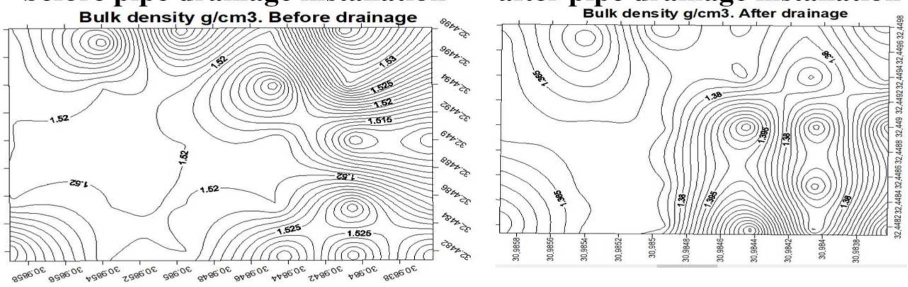

Figure (5). Soil bulk density of soil (g/cm^3) before and after pipe drainage system installation

Soil total porosity

Soil total porosity data are shown in **Figure (6)** presents the mean total porosity values for soil before drainage installation at various depths. The total porosity values at soil depths of 0-50 cm, 50-100 cm, and 100-150 cm were 43.88%, 42.64%, and 42.19%, respectively. For soils with tile drainage systems, total porosity values at these depths were 50.71%, 47.83%, and 47.26%, respectively**.** Tile drainage significantly influenced total porosity. Before the installation of the tile drainage system, total porosity values ranged from 42.1% to 43.4% (average = 42.90%, standard deviation = 1.02). After installation, these values increased to between 47.1% and 49.3% **(**average = 48.60%, standard deviation = 1.67). The beneficial effect of tile drainage on increasing total porosity compared to non-drained soil has been demonstrated, aligning with the findings of **Akatsuka *et al.* (1965), Ramadan *et al*. (1994), and Naguib (2001),** who reported a significant positive increase in drainable pores, rapidly drainable pores, and water-holding pores following drainage installation for all spacing and soil layers. Generally, soil pore space varies with soil type and structure, ranging from 35% to 55% of the total soil volume **(Sands 2001). Pradeep *et al*. (2005)** also observed higher total porosity values in soil after maize harvest in plots with

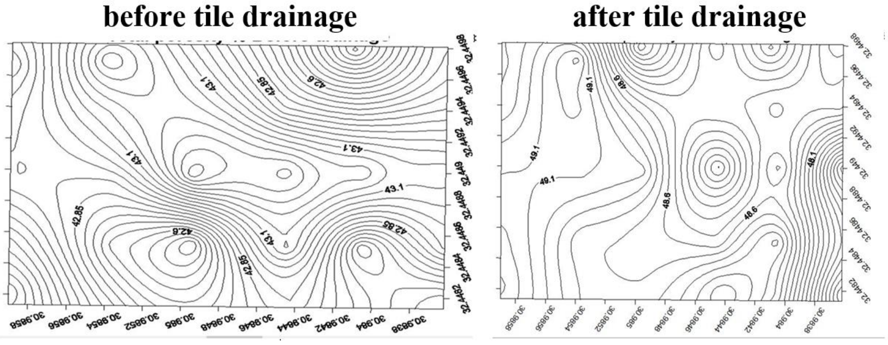

Figure 6: Soil total porosity before and after pipe drainage installation

Infiltration rate

Regarding infiltration rate, data in **Figure (7)** shows that infiltration rates increased after installing the tile drainage system compared to before drainage. Soil, infiltration rates in profiles 3, 5, and 22 were 14.61, 14.56, and 12.40 cm/h, respectively, while the lowest rate was 6.1 cm/h in profile 27 before drainage installation**.**

After tile drainage system installation, infiltration rates in profiles 3, 5, and 22 increased to 18.94, 18.87, and 13.7 cm/h, respectively. The lowest rate of infiltration is 7.76 cm/h in profile 27 **(El-Araby, 1997).** Soil porosity allowed water, air, and nutrients to penetrate the soil. It refers to the spaces between solid particles that hold water and air. The distribution of pore sizes affects the soil's capacity to retain water and air necessary for plant growth. Porosity and pore size distribution influence various soil hydraulic properties, including hydraulic conductivity, water retention, infiltration, and available water capacity **(Indoria *et al.,* 2017).**

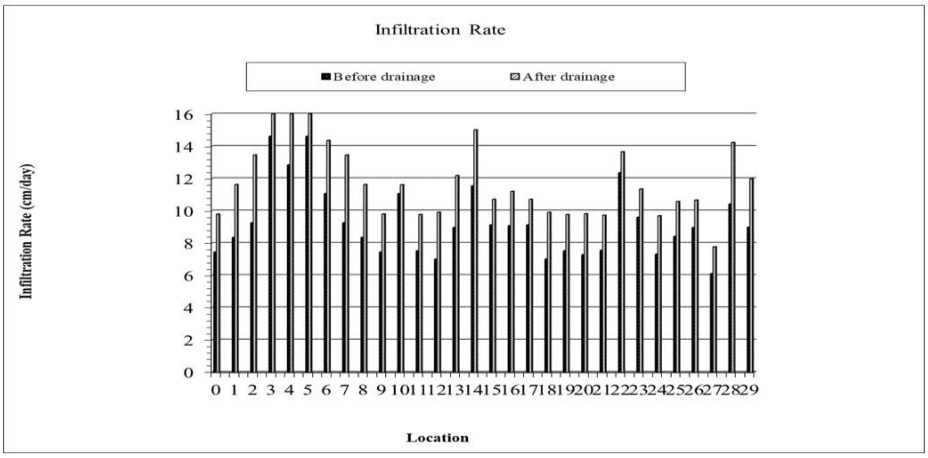

Figure 7: Soil infiltration rate before and after pipe drainage installation

Soil water retention characteristics

The data illustrated in **Figures (8,9, 10, and 11)** highlighted that the installation of tile drainage system significantly affected not only the adjustment of the composition of soil parameters but also saturated water flow and the range of available water. Soil saturation data showed that the saturation percentage (S.P.) ranged from 22.14% to 25.20%, using a mean of 23.64% before drainage. While, after drainage, the saturation percentage ranged from 14.0% to 22.7%, using a mean of 17.1%. Regarding field capacity (F.C.), it ranged from 22.1% (profile 22) to 25.2% (profile 26), using a mean of 23.6.4% before drainage. After drainage installation, it ranged from 14.0% (profile 4) to 22.7% (profile 19), using a mean of 17.1%. For the wilting percentage (W.P.), values ranged from 7.80% (profile 4) to 8.90% (profile 29), using a mean of 8.19% before drainage, and from 4.1% (profile 3) to 7.2% (profile 26), using a mean of 5.8% after drainage. Available water (A.W.) varied from 11.49% (profile 22) to 14.12% (profile 19), using a mean of 13.1% before drainage, and from 7.1% (profile 8) to 10.59% (profile 18), using a mean of 9.2% after tile drainage installation. Table (6) summarizes the mean saturation percentage (S.P.) for soil before drainage installation at different depths: 21.9% at 0-50 cm, 23.8% at 50-100 cm, and 25.3% at 100-150 cm. For soils with after tile drainage, S.P. values were 15.8% at 0-50 cm, 16.3% at 50-100 cm, and 19.3% at 100-150 cm. The mean field capacity (F.C.%) values for soil before drainage at various depths were 19.6% at 0-50 cm, 21.5% at 50-100 cm, and 23.0% at 100-150 cm. For tile-drained soils, F.C.% values were 13.8% at 0-50 cm, 14.3% at 50-100 cm, and 16.3% at 100-150 cm.

Wilting percentage (W.P.%) values for the soil before drainage were 7.9% at 0-50 cm, 8.1% at 50-100 cm, and 8.6% at 100-150 cm. For tile-drained soils, W.P.% values were 5.6% at 0-50 cm, 5.8% at 50-100 cm, and 6.0% at 100-150 cm. Available water (A.W.%) values for soil before drainage were 11.7% at 0-50 cm, 13.3% at 50-100 cm, and 14.4% at 100-150 cm. For tile-drained soils, A.W.% values were 8.1% at 0-50 cm, 9.2% at 50-100 cm, and 10.3% at 100-150 cm.

Overall, soil field capacity, wilting percentage, and available water demonstrated a positive response related to changes in bulk density and total porosity. These parameters influence the creation of micro-pores that enhance water retention through matrix and capillary potentials. Additionally, the presence of fine soil fractions with high concentrations of active inorganic charged colloidal particles, such as charged silicates, affects water retention. Consequently, the relatively coarse texture of the studied soil is linked to its lower capacity to retain moisture available to plants. In this regard, **Tayel *et al.* (2001) and Sands (2001)** suggested that the increase in water retention in relatively coarse soil treated with certain colloidal materials could be attributed to one or more of the following factors: a) A reduction in bulk density of soil and an increase in total soil porosity,.b) Changes in soil composition and consequently alterations in pore size distribution,.c) The superior water retention capacity of colloidal materials compared to sand particles, and. d) An increase in soil hydraulic resistance and a decrease in soil hydraulic conductivity resulting from modifications to soil structure. According to **Chauvin *et al.*, (2011),** soil moisture constants are essential for assessing the moisture content of soil under specific conditions and at any given time. Soil water movement primarily occurs in three forms: saturated, unsaturated, and water vapor.

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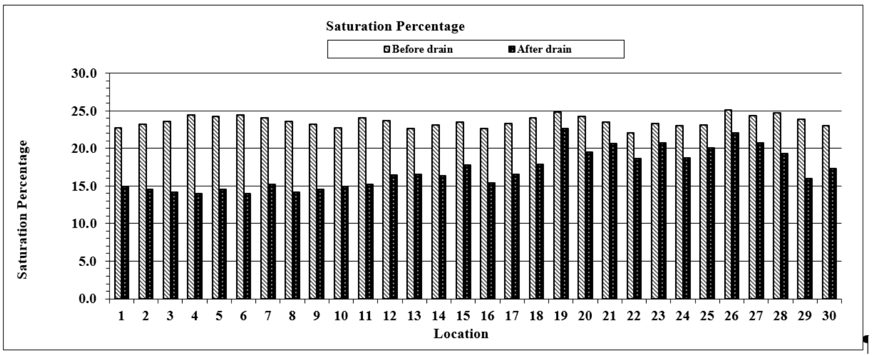

Figure. 8: Soil saturation percentage before and after pipe drainage installation

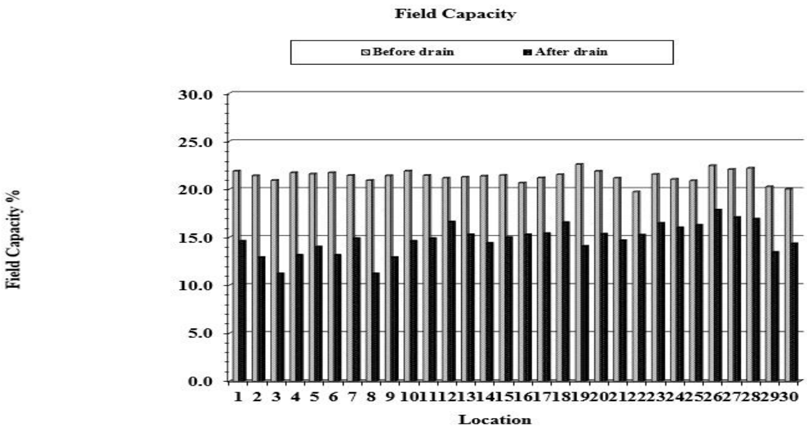

Figure 9: Field capacity before and after pipe drainage installation

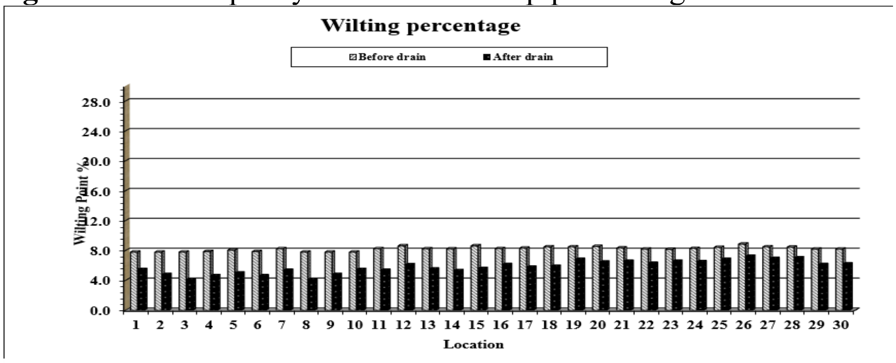

Figure 10: Wilting percentage before and after pipe drainage

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installation

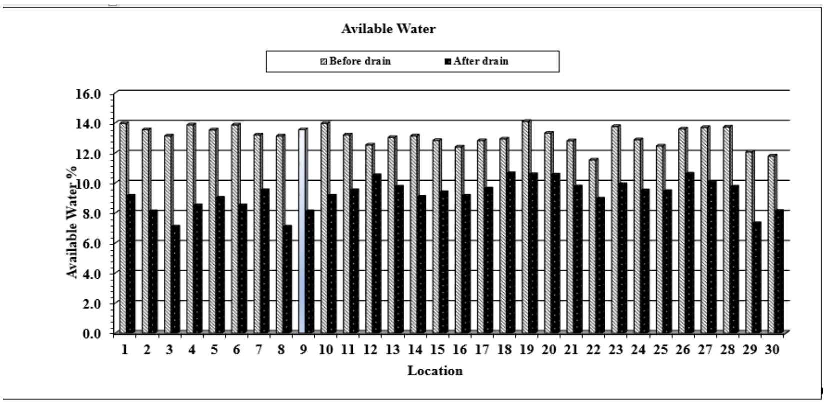

Figure 11: Available water before and after pipe drainage installation

In general, soil physical properties have been improved and enhanced due to the implementation of subsurface drainage, which reduced water table depth of soil to the permissible level for plant growth. At the same time, this affected the formation of more soil aggregates and more macro pores helped removing gravitational water and salts to drains. These results are in agreement with **Han *et al.,* (2023)** and **Sagar *et al.* (2024)** mentioned that subsurface drainage improved the soil physical properties, removed salts, and increased the crop production.

Water table fluctuation

The rise of the water table into the root zone, without adequate drainage leading to soil salinization. The degree of salt accumulation in the soil profile is influenced by several factors: depth of the water table, salt concentration of the water table, soil hydraulic properties, and amounts and distribution of rainfall / irrigation.

Due to the installation of the tile drainage system in the area under study, a substantial reduction in the water table depth was observed. This enhanced the soil water air balance and helps in creating favorable conditions for plant growth. Water table fluctuation is affected by irrigation activities; i.e. after irrigation, the water level rises to maximum height and subsequently declines depending on the soil's physical and hydraulically characteristics. The variations in water table levels before and after the installation of the drainage system are summarized and illustrated in Figure 12. The following observations were made regarding the water table:

Water table depths before and after pipe drainage installation are recognized as the following two days after irrigation (before drainage), water table depths ranged from 18.4 to 26.8 cm, below soil surface with an average of 22.6 cm below the soil surface. After drainage, the depths ranged from 41.3 to 49.2 cm, with an average of 45.25 cm. Five days after irrigation, before drainage, water table depths ranged between 41.6 and 49.1 cm (mean: 43.7 cm). After drainage, the depths varied between 90.4 and 98.2 cm (mean: 92.5 cm).

Ten days after irrigation, before drainage, the depths ranged from 85.4 to 99.3 cm (mean: 88.9 cm). After drainage, the depths dropped further to between 120.3 and 129.4 cm (mean: 122 cm). Two weeks of irrigation, before drainage, the depths ranged from 100.5 to 113.1 cm (mean: 105 cm). After drainage, the depths increased to between 142.7 and 148.7 cm (mean: 144 cm).

The results of the study revealed a significant increase in the water table drawdown following the installation of the subsurface drainage system. The decline in water table levels was most pronounced between four to eight days after irrigation. Fields equipped with tile drainage exhibited a faster reduction in water table depth, with an average decrease of approximately 35% compared to pre-installation conditions.

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before pipe drainage	after pipe drainage

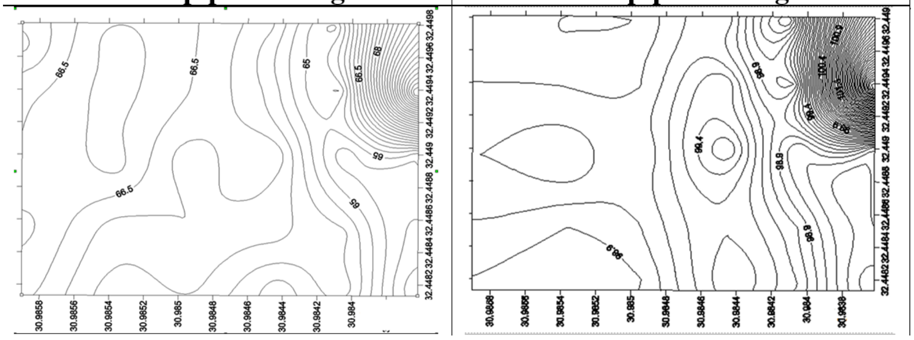

Figure 12: Soil water table depths before and after pipe drainage installation

These results agreed with the findings of **Abd El-Dayem *et al.* (1978)** and **Ibrahim (1992)** whom reported that, without subsurface drainage, groundwater tends to remain near the soil surface during periods of heavy rainfall, leading to inadequate drainage and waterlogging. **Zhou *et al.* (2010)** confirmed a strong relationship between groundwater table management and reductions in soil salinity, emphasizing that effective drainage systems are essential not only for controlling the water table but also for maintaining soil health and productivity.

CONCLUSION

This study demonstrated that the installation of subsurface tile drainage systems substantially improves key physical and hydraulic soil properties. Despite the predominance of sandy to sandy loam soils with naturally low moisture retention, the drainage intervention effectively mitigated these limitations through significant enhancements in soil structure and function. The key findings included, drainage led to a marked decrease in bulk density, indicating reduced soil compaction and improved porosity. Porosity consistently increased at all soil depths, facilitating enhanced aeration and water movement. Water infiltration has improved accelerated the percolation and reduced surface ponding. An improved hydraulic conductivity (K) was recorded, promoting efficient subsurface water flow and minimizing waterlogging risks. Also, field capacity (FC), wilting point (WP), and available water (AW) improved, reflecting better water retention within plant-available pores despite reduced saturation levels, thereby enhancing water use efficiency. The drainage system successfully lowered the water table after irrigation, preventing root zone saturation and salt buildup, fostering better conditions for root growth and crop productivity. Therefore, the subsurface drainage systems should be implemented in suitable soils to improve aeration and reduce salinity, with continuous monitoring of soil moisture and groundwater levels. Drainage design should be tailored to site-specific soil and hydrological conditions, and soil amendments used to enhance water retention. Long-term impact studies and capacity building for farmers and technicians are essential to ensure system effectiveness and sustainability.

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الملخص العربي

الكشف عن التغير في الخصائص والصفات الهيدروفيزيائية للتربة بسهل الطينه ؛ سيناء ؛ مصر تحت نظام الصرف المغطى.

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هدفت هذه الدراسة الى تقييم تأثير الصرف المغطى على الخصائص المائية والفيزيائية للتربه بمنطقة سهل الطينه ؛ سيناء ؛ مصر ؛ حيث نفذت فى مساحة 27.36 فدان تروى بمياة ترعة السلام منخفضة الجودة وزودت المنطقة بنظام صرف زراعى مغطى ؛ بأنابيب تحت سطحية بمسافة بين الخطوط الجانبية تبلغ 40 مترًا وعمق 140 سنتيمترًا، بهدف تحسين إدارة التربة والمياه. وقد أسهم النظام بفعالية في خفض منسوب المياه الأرضية، وتحسين تهوية التربة ونفاذية المياه، كما قلل بشكل ملحوظ من مشكلات ملوحة التربة وقلويتها. أدت هذه التحسينات إلى خلق بيئة تربة أكثر ملاءمة، مما عزز النشاط الحيوي وحافظ على توازن العناصر الغذائية. علاوة على ذلك، ساهم نظام الصرف في تقليل الاعتماد على المصارف السطحية، مما أدى إلى زيادة المساحة القابلة للزراعة. تؤكد النتائج على أهمية الصرف الزراعي تحت السطحي في تعزيز استدامة الزراعة وكفاءة استخدام الموارد وتحسين استخدام الأراضي في المناطق القاحلة وشبه القاحلة. وباختصار، لا يقتصر دور الصرف تحت السطحي على تحسين أداء التربة والمحاصيل فحسب، بل يدعم أيضًا التنمية الزراعية طويلة الأمد في البيئات الغير مستغله والهامشية.

الكلمات الدالة: الصرف تحت السطحي؛ تحسين التربة؛ سهل التينه؛ الخواص الفيزيائية للتربة.