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Subsurface Drainage Impact Assessment in Ibshan, Egypt

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Abstract: This paper aims to mitigate the impacts of subsurface drainage system in Ibshan, Egypt on the environment. For studying and analyzing these impacts, data are collected concerning before and after the installation of the subsurface drainage system. The environmental impacts are set to be crops yields, salinity, and water table depth. Concerning crops yields, five crops are identified to study the effect of the subsurface drainage system on their productivity. Regarding salinity, the saline areas are investigated pre and post the subsurface drainage system. For the water table depth, the ground water table depths are reviewed before and after the subsurface drainage system. Also, the DRAINMOD-S computer program is employed to determine the effect of the subsurface drainage system on the water table depth. It is concluded that the environmental impacts of the subsurface drainage system in Ibshan area are very good. The yields of five crops increased from 7% to 38%, 16.4% of saline areas are improved, and the ground water table depth is reduced by 10%. Also, an equation is obtained to predict the percentage decrease of ground water table depth according to the laterals spacing of the subsurface drainage system.

Key words: Subsurface drainage, crops yields, salinity, water table, DRAINMOD-S, Nile Delta.

1. Introduction

Drainage is one of the most effective means to assure the enhancement of soil productivity and sustainability of agriculture for food production. Subsurface drainage is a good tool to achieve this goal.

In Egypt, more than 2 million fed have subsurface drainage systems. These systems have been designed with fixed drain depths and tile spacing to meet certain strict drainage criteria based on conservative design assumptions regarding crop type and rooting depth.

The crop productivity is the final outcome of the interaction of a variety of factors and determinants of natural, economic, social, regulatory, and legislative nature. The natural factors come at the forefront affecting factors on the agricultural production. Whereas, the crop productivity reflects the impact of these factors combined.

The effect of subsurface drainage on crop yield showed an increase in the yields of rice, sugarcane, wheat, sugar beet and tobacco, while the yield of cotton crop was relatively low mainly due to the shortage of irrigation supplies [1].

The effect of subsurface drainage on soil salinity showed that the surface and profile salinities were significantly decreased by 20% and 14%, respectively with respect to the pre-project [2].

The benefits of subsurface drainage systems were associated with negative impacts such as pollution of drainage water with salts, nutrients, organic components, and harmful minor elements like heavy metals [3].

DRAINMOD-S and SWAT (soil and water assessment tool) are two popular water table

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management models developed to predict drain flow rates [4]. A finite difference solution of the Richards's equation is employed by a simulation model of the SWAT, while the Hooghoudt and Kirkham equations in terms of mid-space water table elevation between drains are followed by DRAINMOD-S.

The rate of water movement into drains depends on the hydraulic conductivity of the water flow domain of the surrounding soil, drain spacing and depth, soil profile depth, and water table elevation.

DRAINMOD-S model was evaluated under semi-arid conditions in Maruit in the western delta of Egypt for three cropping seasons [5]. The reliability of the model was evaluated by comparing measured and predicted values of the daily ground water table depth, cumulative outflow based on total monthly outflow, soil salinity during each season, and relative crop yield. Good agreements were found between the measured and predicted values.

This paper aims to mitigate the impacts of subsurface drainage system in Ibshan, Egypt on the environment. Ibshan area is located in northeastern part of the Nile Delta 120 km away of Cairo.

The area is approximately 5,000 feddans. This area has been selected based on its wide range of geo-hydrological, climatic and socio-economic conditions as well as availability of soil salinity data. The subsurface drainage system in Ibshan area was constructed by EPADP (Egyptian Public Authority for Drainage Projects) since 1995. The design of the subsurface drainage system was made according to the standard criteria of EPADP. The drains depths are 1.50 m for laterals and 2.5 m for collectors. The spacing between laterals is 60 m.

2. Analyses of the Data

In this paper the environmental impacts are set to be crops yields, salinity, and water table depth. For studying and analyzing these impacts, data are collected concerning before and after the installation of the subsurface drainage system. The collected data are first screened for their integrity, and then are analyzed to assess the efficiency of the subsurface drainage system with respect to the above stated environmental impacts.

For the first environmental impact concerning crops yields, five crops are identified in Ibshan area to study the effect of the subsurface drainage system on their productivity. In the summer season the crops are cotton, maize, and rice. While in the winter season the crops are wheat and beans. It has to be mentioned that these crops are very important in Egypt. They represent 60% of the total cultivated area, and they are the most famous import and export crops that affect greatly the Egyptian national economy.

For the second environmental impact concerning salinity, the saline areas in Ibshan are investigated pre and post the subsurface drainage system.

For the third environmental impact concerning the water table depth, the ground water table depths in Ibshan are reviewed before and after the subsurface drainage system. Also, the DRAINMOD-S computer program is employed to determine the effect of the subsurface drainage system on the water table depth in Ibshan. Observation points are selected all over the area of the subsurface drainage system in Ibshan. These points are located at distance of 100 m from the canals or drains, and at distance of 70 m-120 m from the collectors. The distance between each two observation points is 400 m-500 m.

3. Results and Discussion

For the first environmental impact concerning crops yields, five crops are identified in Ibshan area to study the effect of the subsurface drainage system on their productivity. In the winter season the crops are wheat and beans. While in the summer season the crops are rice, cotton, and corn. It has to be mentioned that these crops are very important in Egypt.

In Ibshan area, the average yields pre the subsurface drainage system (1990-1995) and post the subsurface drainage system (1996-1998) for the five major crops

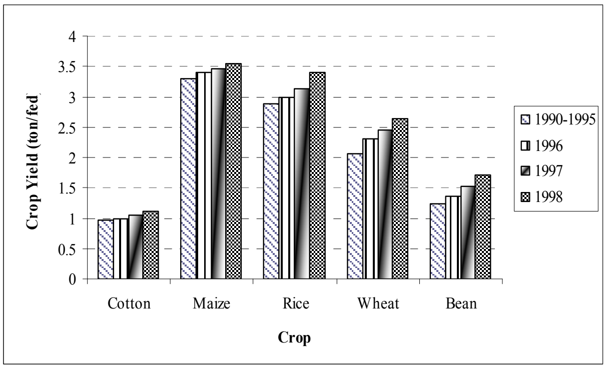

Fig. 1 The average yields pre and post the subsurface drainage system.

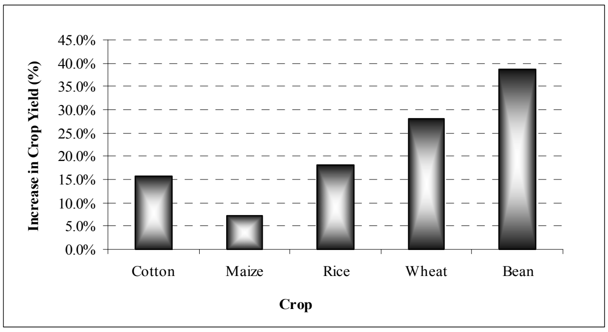

Fig. 2 The post subsurface drainage system percentage increases in the yields of crops.

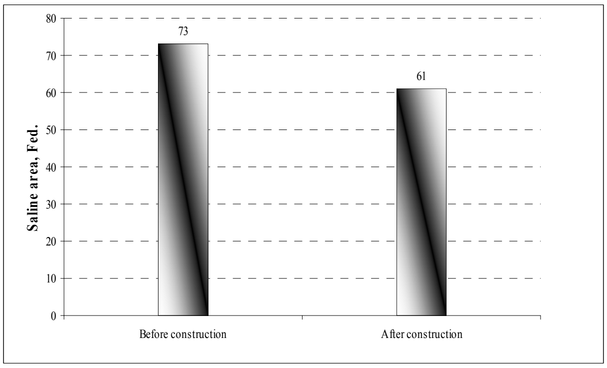

Fig. 3 The saline areas before and after the subsurface drainage system.

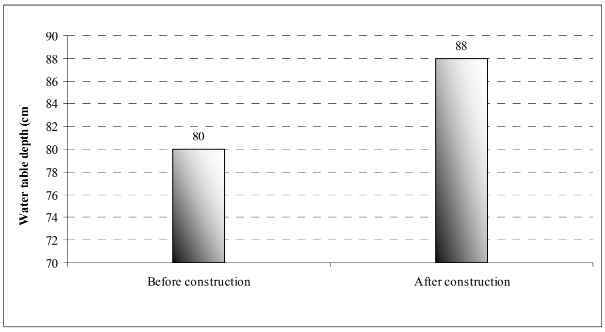

Fig. 4 The water table depths before and after the subsurface drainage system.

are graphically represented in Fig. 1. There is a significant increase in the yields. The post subsurface drainage system percentage increases in the yields of cotton, maize, rice, wheat, and bean are 15.6%, 7.3%, 18.1%, 28.2% and 38.7%, respectively, as illustrated in Fig. 2.

For the second environmental impact concerning salinity, soils with an EC (electric conductivity) greater than 4 dS/m are considered saline. Actually, salt-sensitive plants may be affected by electric conductivities less than 4 dS/m. Thus, for land reclamation, salinity should be defined in terms of the pre-disturbance land use potential, the proposed post-disturbance land use, and the plant species to be seeded on the site [6].

However, the saline areas in Ibshan were 73 feddans before the subsurface drainage system. These areas are reduced to 61 feddans after the subsurface drainage system, as illustrated in Fig. 3. The percentage of improved areas is 16.4%. This reduction in saline areas means increasing cultivated lands that give more crops yields for people and the country as a whole.

For the third environmental impact concerning the water table depth, observation points are selected all over the area of the subsurface drainage system in Ibshan as mentioned before. The water table depth is measured from the ground surface to the water table.

The average water depths before and after the subsurface drainage system are 80 cm and 88 cm respectively, as shown in Fig. 4. This reduction in water table depth due to the subsurface drainage system in Ibshan area is 10%.

The ground water table management simulation model, DRAINMOD-S, is employed to evaluate the water table depth with different subsurface drainage spacing [4].

As shown in Fig. 5, there are two basic equations of DRAINMOD-S for water balances for a time increment, Δt = 1h.

The first equation concerns the water balance for a thin section of soil of unit surface area that extends

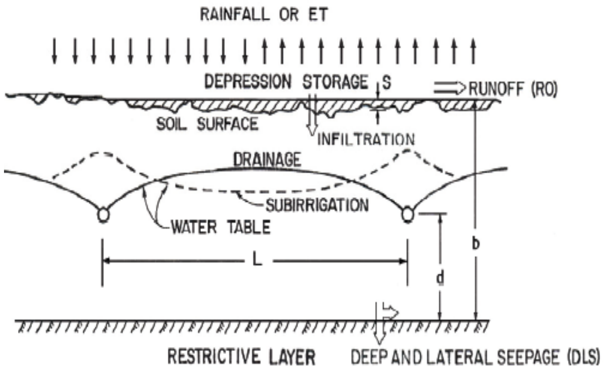

Fig. 5 Principal hydrologic components of a subsurface drainage and water table management system [4].

from the impermeable layer to the surface and is located midway between adjacent drains.

$$\Delta va = D + ET + DS - F \quad (1)$$

where,

Δva : change in air volume (cm);

D: lateral drainage (cm);

ET: evapotranspiration (cm);

DS: deep seepage (cm);

F: infiltration (cm).

While the second equation concerns the water balance at soil surface.

$$P = F + \Delta S + Ro \quad (2)$$

where,

P: precipitation (cm);

F: infiltration (cm);

ΔS: change in volume of water stored on surface (cm);

Ro: runoff (cm).

In this paper, the DRAINMOD-S program is employed for five cases. The first case assumes no subsurface drainage system. The other four cases are set for the subsurface drainage system with spacing between laterals of 20 m, 40 m, 60 m and 80 m. The laterals level is at 150 cm from the ground surface. The program is carried out for a year. Fig. 6 shows the water table depths for different subsurface laterals spacing.

The lowest ground water table depths are got for laterals spacing of 20 m. While at the laterals spacing of 80 m, there is almost no effect on the ground water table depths.

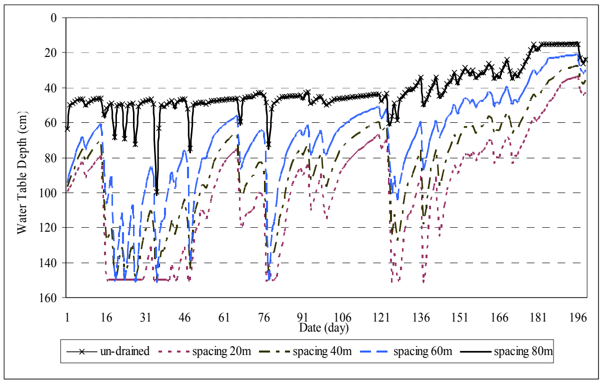

Fig. 6 Water table depth for different subsurface laterals spacing.

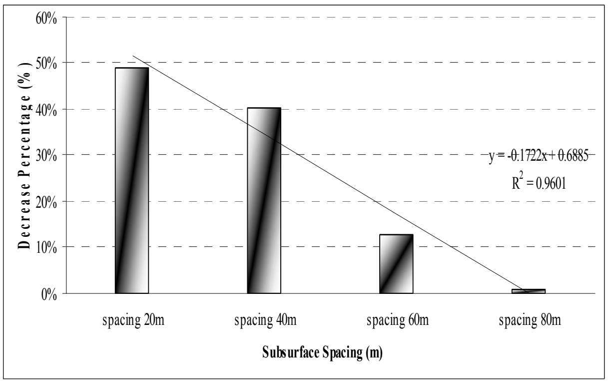

Fig. 7 The relation between the percentage decrease of ground water table depth and the subsurface laterals spacing.

The decreases of ground water table depths are considered as percentage ratios, and are illustrated in Fig. 7. It is obvious that the subsurface laterals spacing of 20 m is associated with the most decrease of about 49%. While the subsurface laterals spacing of 80 m is associated with the lowest decrease of about only 1%. The water table depth is reduced by about 10% when the subsurface laterals spacing is changed from 20 m to 40 m.

For the relation between the percentage decrease of ground water table depth and the subsurface laterals spacing, a linear regression analysis is adapted employing micro soft excel software, as shown also in Fig. 7.

The obtained equation is:

$$D = -0.1722\, S + 0.6885 \quad (3)$$

where,

D: the decrease of ground water table depth (%);

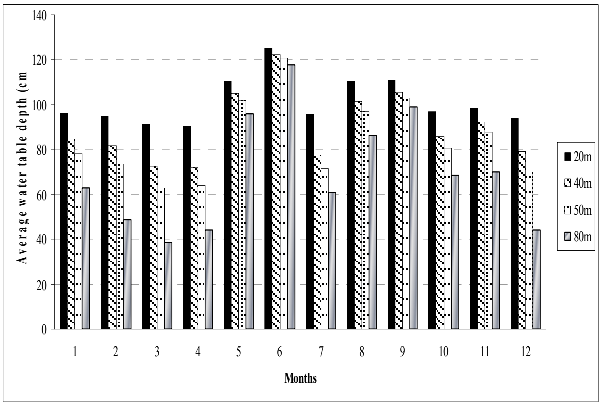

Fig. 8 The average water table depths in different months for different laterals spacing.

S: the laterals spacing of the subsurface drainage system (m).

For different laterals spacing, the average water table depths in different months are shown in Fig. 8.

4. Conclusions and Recommendations

It is concluded that the environmental impacts of the subsurface drainage system in Ibshan area are very good. The yields of five crops increased from 7% to 38%, 16.4% of saline areas are improved, and the ground water table depth is reduced by 10%.

An equation is obtained to predict the percentage decrease of ground water table depth according to the laterals spacing of the subsurface drainage system.

It is recommended to apply the obtained equation to other different areas, and compare its results with the records of pre and post subsurface drainage systems.

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