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Water Resources Management: Case Study of El Minia Governorate, Egypt

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Abstract: Ministry of water resources and irrigation in Egypt is currently implementing projects that expand new cultivated area, as a consequence the supplies of Nile River to the existing lands will be affected. Because Egypt is an arid country with hardly any rainfall, water shortage is a major problem facing any development in Egypt, so water management is of paramount importance. The present paper aims to investigate the various options for the water resources management in El Minia governorate, one of the major provinces in Egypt. A complete map of the water resources has been prepared including irrigation and drainage processes. In addition, the political needs for distribution, management and control of the water resources have been taken into consideration. The main features of one of the famous commercially available unsteady simulation software package, the Operational Planning Distribution Model (OPDM), has been described and used to simulate water distribution system and crop yield. It has been also implemented to the selected case study to develop appropriate water plan. As the weather condition is an important factor that affects crops consumptive use of water, the monthly rate of sunlight hours, rainfall, wind speed, evaporation and relative humidity have been considered during the study period. Furthermore, the impact for allocation of the irrigation water has been investigated. Moreover, the different options have been compared from technical and economical points of view. Finally, effect of variation in both surface and groundwater quantities and qualities on the gross revenue has been presented.

Keywords: Water Resources Management, El Minia governorate, Egypt, OPDM, Modelling.

1 Introduction

Water is the most important natural resource that can be utilized by man to develop his prosperity as well as his essential needs. Water resources management, water pollution control and environmental protection are the main issues to safeguard this resource. The challenges of managing water resources for a multiplicity of uses and threats must be set within the much broader contexts of changes in the economic, social and political landscapes.

Egypt is located in the arid zone of North Africa where the fresh water resources are limited to the fixed share from the Nile and groundwater systems. Growing population, agricultural expansion, and urbanization has placed a heavy demand on water resources, Ahmed A. and Ali M. (2009).

The overpopulation problem in Egypt is the mother of all others. This problem has two aspects first the high rate of increase, second is the unique way of distribution where 98% of the people live on 5% of the state (that is the area of the Nile delta and its narrow valley), whereas 2% occupy the vast desert which represents 95% of Egypt. Accordingly the redistribution of the population over the state area is a must. If we accept that the existing population will continue to occupy 5% of our land so we must move 33 millions to other regions during the next 30 years which means the movement of more than one million per year, El Atfy et al. (2004). So we must return back and try to widen the narrow valley and try to redistribute ourselves. To relieve the pressure on the Nile Valley and Delta, the government has embarked on ambitious program to increase the inhabited area in Egypt by means of horizontal expansion projects in agriculture and the creation of new industrial areas and cities in the desert. All these developments need water.

Nile River is considered the main water source in Egypt, while the second water source is groundwater especially in desert areas. It is estimated that the Nile provides 95% of the country's fresh renewable water supply, NWRP 2003. Agriculture is almost totally dependent on the Nile. The rapid in population growth, agricultural extension, and urbanization are big challenges to the country in relation to water scarcity.

2 Literature Review

A search of the literature reveals a wide range and number of published reports regarding river basin models of which a few studies represent basin wide integrated modeling. These studies are presented under broad categories as (Water Resources Analysis and Mathematical Evaluation, Physical and Mathematical Simulation Models, Mathematical Optimization Models and GIS-Based Decision Support Systems).

The measures to make better use of existing resources aim at improving the efficiency of the water resources system. They include a careful evaluation of planned horizontal ex-

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pansion projects and a scheduled implementation of the projects in relation to the availability of required water. Previous investigations on water resources management in Egypt are numerous, e.g. Abdel-Aziz (2002), presented a brief study for the cost recovery in water systems. Also El Atfy et al. (2004), introduced a study about water valuing and presented a tool for demand management in Egypt. In addition, there are many researches in the field of water policy integration in Egypt, e.g. NWRP (2003).

Over the last twenty years, digital representations of the Water Resources Management (WRM) have become increasingly available in the form of digital models (DMs). Using computers and extracting data from digital models is faster, and provides more reproducible measurements than traditional manual techniques. Mohan Zade et al. (2005), made an attempt to quantify the runoff potential for all basins of India using remote sensing data. Anandan and Venkatesh (2005), implemented GIS as a tool to estimate the surface water potential. Two other management dimensions that deserve special mention are the regional hydro-politics in the Nile Basin, driven by ever stronger claims on the part of upstream countries for a higher share of the river runoff, and the increasing budgetary pressures on the water agencies, Luzi (2010). Cecilia et al. (2008), draw on the policy network perspective on governance to shed light on the strengths and weaknesses of watershed-based processes of collaboration and integration for water quality protection in agricultural areas. El Bedawy (2014), establishes a well coordinated information system to support decision makers for making an effective water resources management on an environmentally sound basis.

The present paper analyzes studied region's water policy planning and proposes to highlight the characteristics of this planning effort. The Operational Planning Distribution Model (OPDM) was used to simulate water distribution system and crop yield through the studied region. Moreover, the software package is used to assess the impact of allocation of the irrigation water. Finally, the gross revenue of all crops is correlated to surface and ground water quantities and qualities.

3 Model Description

The Operational Planning Distribution Model, OPDM, is one of the most improved software developed for performing simulation of water distribution and crop yield response for irrigation and other uses in complex canal and drainage networks. The OPDM is mainly used to calculate the crop water requirements based on the specified cropping patterns and weather information. The simulated flows are then routed through a system of a main supply source, groundwater aquifers, downstream sources, and open drains.

4 Theoretical Approach

Different model parameters are calculated theoretically in the model as wind speed adjustment, the leaching fraction, the deficit yield reduction equation, salinity yield effect during crop growth stage and evpotranspiration using Penman-Monteith equation.

$$U_2 = 4.852 U_z / \ln(z - 0.08/0.015) \qquad (1)$$

Where: U_2 is the equivalent wind speed at 2.0m height (m/s); and U_z is the measured speed at a height of z above the ground surface (m). The denominator in Eq. (1) involves a natural logarithm term (base e). When z is equal to 2.0 the value of U_2 will be equal to U_z.

$$LF = EC_{iw}/EC_{dw} = D_{dw}/D_{iw} \qquad (2)$$

Where: LF is the leaching fraction (from 0 to 1.0); EC_{iw} is the electrical conductivity of the irrigation water (dS/m); EC_{dw} is the electrical conductivity of the drainage, or deep percolation, water (dS/m); D_{dw} is the depth of drainage water (m); and D_{iw} is the depth of infiltrated water from the soil surface (m).

$$Y_{rel} = 100 \prod_{i=1}^{n} \left(ET_a / ET_p \right)_i^{\lambda_i} \qquad (3)$$

Where: Y_{rel} is the relative yield (%); ET_a is actual transpiration (mm/day); ET_p is the maximum potential transpiration; λ is a fitted exponent (a calibrated value); and the subscript i refers to the growth stage (the OPDM uses three growth stages, so, n = 3).

$$Y_{rel} = 100 - B_s \left(EC_e - A_s \right) \qquad (4)$$

Where: Y_{rel} is the relative yield (%); A_s is the threshold salinity (dS/m); B_s is the rate at which relative crop yield declines with increasing salinity, beyond A_s (% per dS/m); and EC_e is the salinity of the soil water extract (dS/m).
The various forms of the Penman equation belong to the combination method. The combination method produces some of the most complex ET_o equations. The following form of the Penman equation, called Penman-Monteith:

$$ET_o = \frac{0.408 \Delta \left(R_n - G \right) + \dfrac{890 \gamma U_2 \left(e_a - e_d \right)}{T + 273}}{\Delta + \gamma \left(1 + 0.339 U_2 \right)} \qquad (5)$$

Where ET_o in mm/day for a grass reference crop; Δ is the slope of the saturation vapor pressure function (kPa/ C); γ is a psychrometric constant (kPa/ C); R_n is the net solar radiation (MJ/m^2/day); U_2 is the wind speed (m/s) at 2.0m height; T is the mean daily air temperature (°C); $e_a - e_d$ represents the saturation vapor pressure deficit of air (kPa); and G is the soil heat flux density (MJ/m^2/day).

5 Case Study

5.1 Project Area

The irrigation project area located at El Minia Governorate, one of the major provinces in Egypt, is taken as the case study. The area is irrigated through a network of irrigation canals and some water is pumped from an aquifer and used for irrigation along with the surface water. The basic data of the pro-

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ject area and the base case that is taken as the control case for comparison is displayed in the following.

El Minia Governorate is bounded on the north by Benisuef Governorate, on the south by the Governorate of Assiut and New Valley. It extends to the east governorate of the Red Sea and to the west Giza Governorate, as shown in Fig. 1.

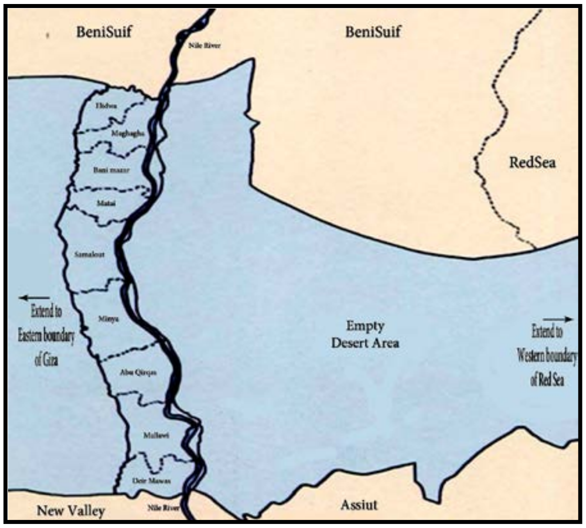

Fig. 1. The Boundaries of El Minia Governorate

The governorate is divided administratively into 9 centers are Maghagha, Adwa , Bani mazar, Samalout, Minia , Matai , Abu Qirqas , Mallawi and Deir Mawas, as shown in Table 1.

The project area, consists of open canals as shown in Fig. 2, is located between latitude 27.35° N and 28.46° longitudinal at an elevation of 43 m above the mean sea level. The cropping patterns used in simulation are winter and summer cropping pattern. The time period considered for study one year. The wind speed used in calculating the evapotranspiration is 2.0m above ground surface.

Table 1. Description of Project Area

Command Area	Area (Feddan)
Elidwa	62627
Maghagha	75884
Bani Mazar	94955
Matai	65818
Samalout	109928
Minia	108259
Abu Qirqas	92654
Mallawi	103622
Deir Mawas	55341

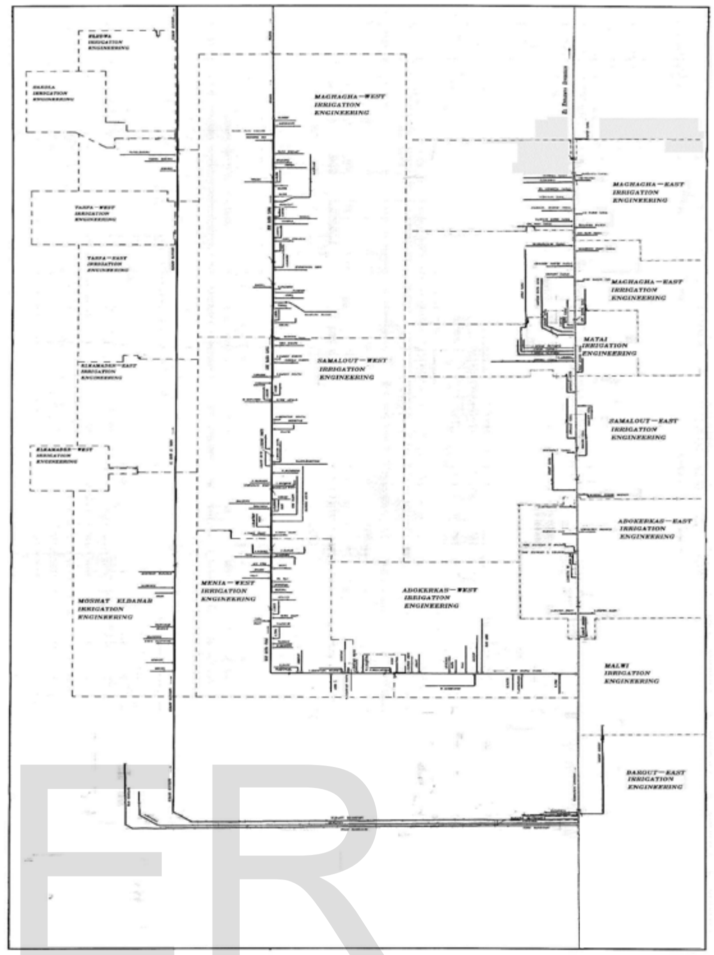

Fig. 2. A schematic view of the case study

5.2 Description of Soil

Soil formed by deposition of sediment the river of mud and silt during floods, which lasted from August to October and represents the soil most of the territory of Minia governorate near the border of the eastern highlands and even the western desert. Calcareous soil covered the land available for the eastern highland regions near the Matay and Maghagha and Bani Mazar. According to land soil salinity, land which the degree of electrical conductivity in which 48 milimose/cm, and this land is located in the area between Ibrahimeya Canal and Sea Joseph, which frequently Avaliable in Maghagha, Bani Mazar, Mallawi, and El Edwa .

5.3 Cropping Pattern

The summer rotation crops represent the most intensive crop irrigation water by virtue of climatic conditions where very high rates of evaporation occur and raising the consumption of water for crops during the summer months. The cropping pattern for the project area is included different crops like Clover, Grape, Groundnuts, Maize, Potatoes, Sesame, Sorghum, Soybean, Sugarbeet, Sugarcane, Vegetables and Wheat.

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5.4 Water Use

The volume of water discharged from the province of Minia in 2010, about three billion cubic meters, as shown in Table 2 and Table 3.

Table 2. The Water Use

Water use	Amount MCM	%
Agriculture	2582.3	85
Drinking	91.66	3
Industrial	0.025	0.0008
Cultivate losses	328.3	10.8
other	35.1	1.2
Total losses	363.4	12
Total	3037.4	100

Table 3. Groundwater Use

Water use	Total amount	Surface water	%	Ground water	%
Irrigation	3622.6	2910.1	80.2	712	19.7
Drinking	225.4	126.8	56.02	98.7	43.8
Industrial	0.065	0.065	38.5	0.04	61.5
Total	3848.1	3037.4	79	810.7	21

5.5 Weather Data

The weather condition is an important factor that affects crops consumptive use of water and the evaporation. The Monthly Rate of sunlight hours, rainfall, wind speed, and relative humidity are presented in the Tables from 4 to 8 at El Minia and Malawi Stations.

Table 4. Monthly Rates for Sunshine (hr/day)

Month	Actual	Theoretical	Rate, Brightness
December	8.2	10.6	7.6
January	6.7	9.8	
February	8.1	10.2	
March	9.4	12.5	10.7
April	11.2	14.1	
May	11.6	14.6	
June	12.5	14.7	12.4
July	12.6	14.7	
August	12	13.5	
September	11	13.3	10
October	10	11.8	
November	9.2	10.8	

Table 5. Rain Fall Depth

Month	Rain fall (cm)
December	0.7
January	0.5
February	1
March	0.9
April	0.2
May	0.3
June	0
July	0
August	0
September	0
October	0.3
November	0.7
Annual rate	4.6

Table 6. Evaporation (mm)/day

Month	Minia Station	Malawi Station	Average
December	5.9	5.4	5.6
January	6.6	5.8	6.4
February	7.1	6.2	6.7
March	10.2	8.4	9.3
April	11.5	10.9	11.2
May	16.6	13.2	14.9
June	17.1	15.2	16.1
July	15.3	12.1	13.7
August	12.8	10.8	11.8
September	11.2	9.2	10.2
October	10.7	9.1	9.9
November	8.1	7.5	7.8
Annual	11.1	9.5	10.3

Table 7. Wind Speed

Month	Minia Station	Malawi Station	Monthly Rate	Seasonally Rate
December	4.1	6.6	5.4	5.7
January	5.6	5.8	5.7	
February	5.8	6.3	6	
March	7.1	7.2	7.1	7.9
April	7.7	8.1	7.9	
May	84	9.3	8.8	
June	8.8	8.4	8.6	7.3
July	6.2	6.7	6.4	
August	6	8.1	7	
September	6.5	6.1	6.3	6.2
October	6.8	5.5	6.1	
November	5.6	6.8	6.2	

Table 8. Relative Humidity (%)

Month	Minia Station	Malawi Station	Monthly Rate
December	60	63.5	61.8
January	52	66.2	59
February	50.1	57.2	53.6
March	47.3	51.2	49.2
April	38.5	40.1	39.3
May	33.2	35.2	34.2
June	32.5	34.5	33.5
July	36.8	39.6	38.5
August	44.2	42.1	34.1
September	47.3	51.2	49.2

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October	45.1	53.2	49.2
November	55.6	60.1	57.8

6 Base Case

The system layout was simulated, as shown in Fig. 3. The base case taken as a reference for comparison with the proposed scenarios depends on the parameters presented in Table 10. For the Base Case, the surface water discharge is 92.5 m^3/sec. The project gross revenue is 4.089 Mil Million EGP. The Table 11 and 12 show the details of gross revenue by crops and command area respectively.

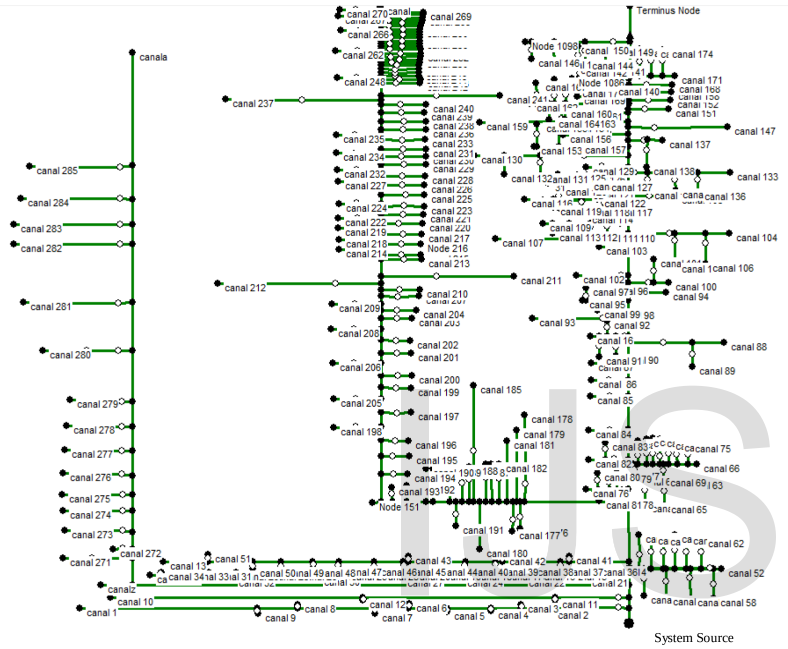

Fig. 3. System Layout

Table 10. Water Resources Quantity and Quality for Base Case

Surface Water discharge (m^3/sec.)	92.5
Salinity of surface water (ds/m)	1.0
Ground water discharge (Million m^3/year)	60
Salinity of groundwater (ds/m)	4.0

Table 11. The Gross Revenue of the Base Case by Crops

Crop	Gross revenue (Million L.E)
Clover C	618.211
Grape	112.311
Groundnuts	68.713
Kozbarah	177.207
Maize N	1034
Potatoes N	659.269
Sesame	44.172
Sorghum N	101.324
Soybean	58.854
Sugarbeet	32.982
Sugarcane	271.585
Tomatoes	215.593
Wheat	694.398
Total gross revenue (Million LE)	4089

Table 12. The Gross Revenue of the Base Case by Command Area

Command Area	Gross revenue (Million L.E)
Der mwas	296.561
Malwy	291.851
Abo Kerkas	418.085
Minia	826.477
Smalot	638.060
Matay	457.330
Bni mazar	398.182
Maghaghah	457.330
Edwah	398.182
Total gross revenue (Million LE)	4089

7 Scenarios

Different scenarios to take place in the future due to expected water resources crisis are considered. These scenarios include changes in discharge and salinity of both surface water and ground water. Group 1 of scenarios represents a decrease in available surface water while group 3 includes a decrease in available groundwater. Group 2 and group 4 study the effect of increased salinity of surface water and that of groundwater, respectively.

These scenarios covered a wide range of changes in both surface and groundwater quantity and quality. The decrease in quantity of both surface water and groundwater ranges from 5% to 30% with a 5% increment. The increase in salinity of surface water ranges from 50% to 300% with a 50% increment. The increase in salinity of ground water ranges from 12.5% to 75% with a 12.5% increment. The results of all scenarios are studied to investigate the effect of these changes on the gross revenue of the project area.

8 Analysis of the Results

The results obtained by the twenty four scenarios are presented in the following part. Fig. 5 and 6 show the Evapotranspiration by command area and crop type for base case. It is clear that Maghaghah and Abo Kerkas represent the highest

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centers while Maize, sugarcane and wheat are the highest crops in consumptive use.

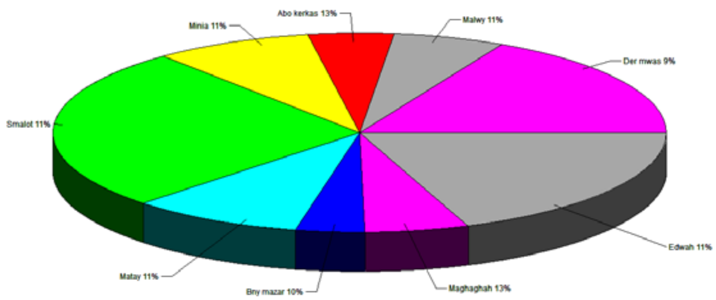


Fig. 5. Evapo-Transpiration by Command area for Base Case

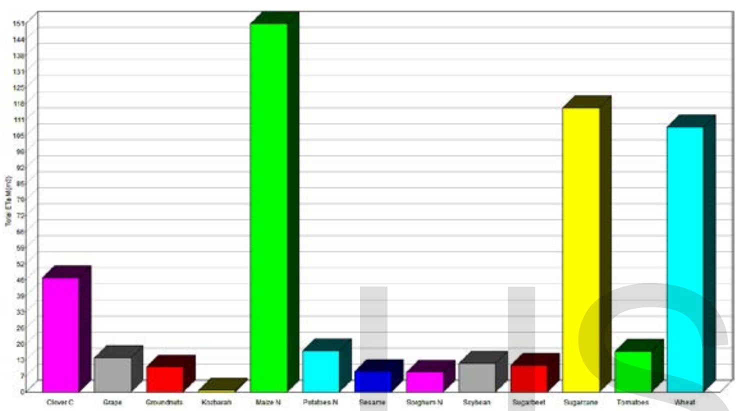
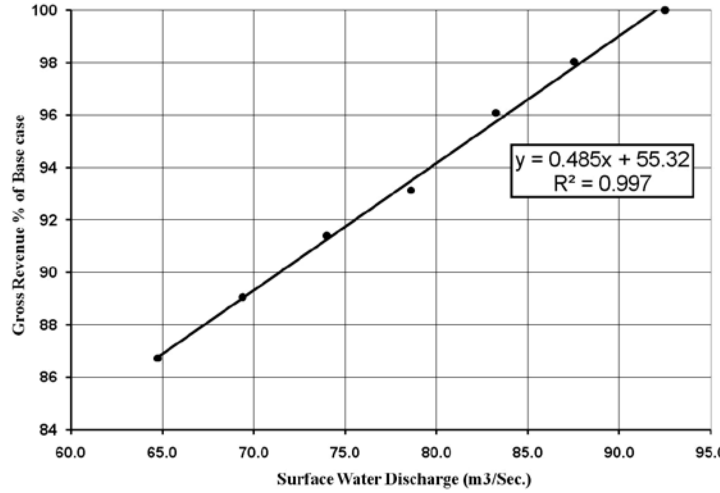


Fig. 6. Evapo-Transpiration by Crop Type for Base Case



All scenarios were treated by the OPDM model. Fig. 7 and 8 show that the reduction in surface water quantity reduces the gross revenue of the project area. Fig. 9 shows the effect of increasing surface water salinity. It is clear that as the salinity of surface water increases, the gross revenue of the project area decreases. This is due to the fact that any increase of water salinity above certain values affects the yield of crops.

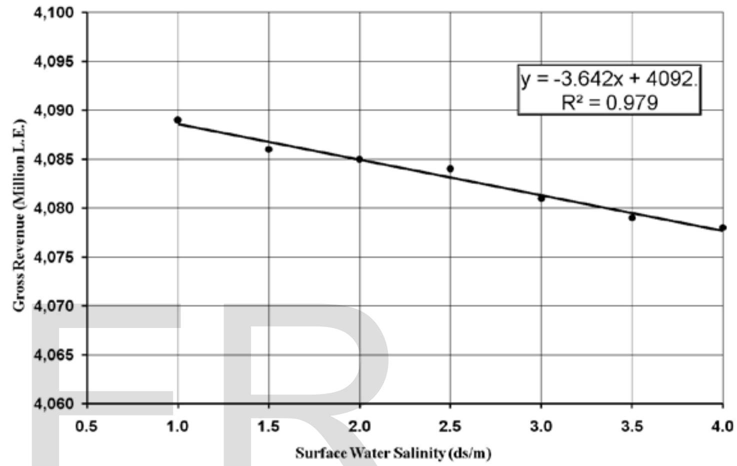


Fig. 9. Relation between Surface water Salinity and Gross Revenue

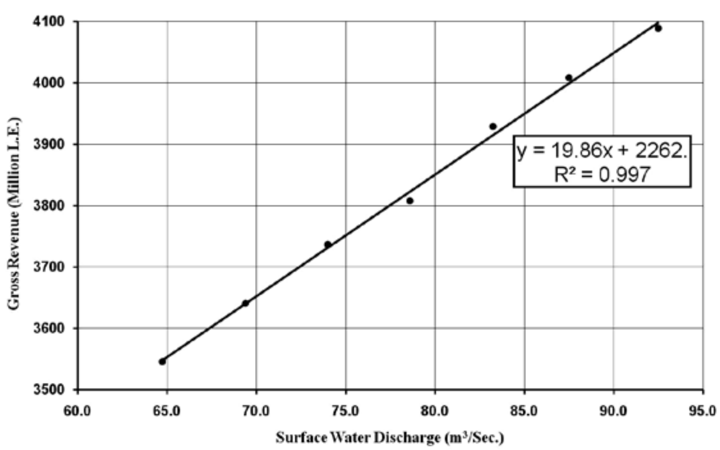


Fig. 7. Relation between Surface Water Discharge and Gross Revenue

In Fig. 10 the effect of decreasing available groundwater is investigated. It is obvious that the reduction of available groundwater quantity reduces the gross revenue of the project area.

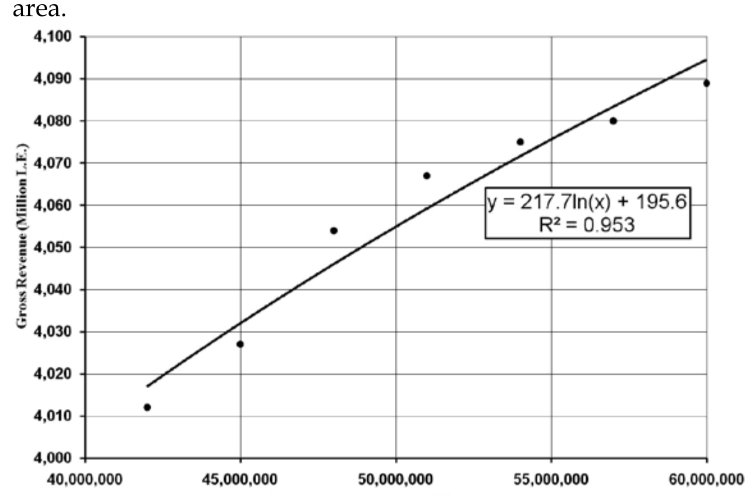


Fig. 10. Relation between Groundwater Discharge and Gross Revenue

Fig. 11 emphasizes that the increase of groundwater salini-

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ty affects the gross revenue of the project area. However, this effect is less compared to that in case of surface water.

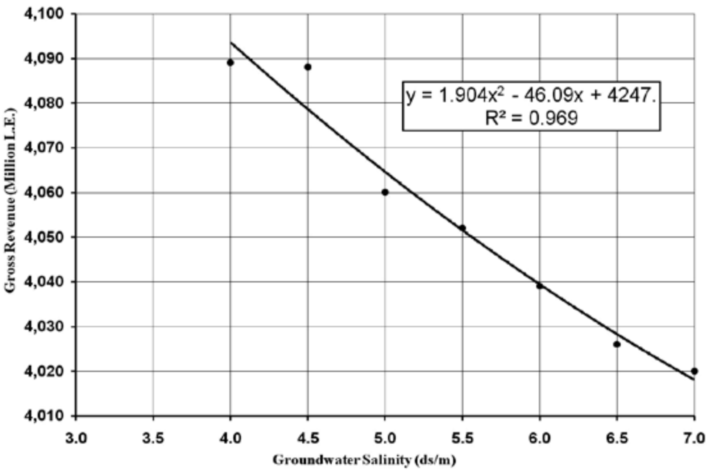

Fig. 11. Relation between Groundwater Salinity and Gross Revenue

From the previous figures, the discharges for both surface water and groundwater were reduced relative to the base case, as it probably occurred in the future. In the contrary, the surface water and groundwater salinities were increased, thus reduce the gross revenue. It was found that the effect of reducing surface water quantities on the gross revenue is larger than the effect of reducing the groundwater quantities through the simulation model. Another example that offers insights into processes of water resource management in El Minia Governorate are the recent attempts to shift cropping patterns toward less water-consuming crops. That can be done by controlling the area grown by some crops such as Maize and sugrecane.

9 Conclusions

The government of Egypt affords great role to the management of water resources especially with expanding the cultivated areas to meet the increasing growth of population. Accordingly, the supplies of Nile River to the Nile Delta will be negatively affected. In the present study, the OPDM is implemented on El Minia governorate to show the effect of water resource management on the gross revenue. The gross revenue of all command areas is correlated to surface water discharge, ground water discharge, surface water salinity, and ground water salinity. It is cleary found that the gross revenue decreases as the surface water and groundwater discharges decrease. The effect of reducing surface water quantities on the gross revenue is larger than the effect of reducing the groundwater quantity in simulation model. In addition, the gross revenue decreases as the surface water and groundwater salinities increase. The gross revenue of the project area in simulation model at any value of dependant variable, with other variables constant, can be calculated using the optained simulation equation. The derived equations for calculating the gross revenue as a function of water quantity or quality are of acceptable reliability. Furthermore, other scenarios for new studies should be carried out to clarify the economic and social effects due to change crop patterns on El Minia governorate.

10 Nomenclature

A_s is the threshold salinity (dS/m),
EC_e is the salinity of the soil water extract (dS/m),
ET_o is the potential evapotranspiration (mm/day),
R_A is extraterrestrial solar radiation (equivalent mm/day),
T is the mean daily air temperature (°C),
T_{max} is the maximum daily air temperature (°C),
T_{min} is the minimum daily air temperature (°C),
Δ is the slope of the saturation vapor pressure (kPa/C),
γ is a psychrometric constant (kPa/ C),
R_n is net solar radiation (MJ/m²/day),
U_2 is the wind speed (m/s), and
G is the soil heat flux density (MJ/m²/day).

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