The 2nd International Conf. on Water Resources & Arid Environment (2006)

Maximizing the Net Present Value of the Drainage Water Reuse Projects: Model Sensitivity

Ahmed Mohamed El-Hawary

Drainage Research Institute, National Water Res., Center, Egypt

Abstract

A model for maximizing the economic return of drainage water reuse in irrigation was developed. It selects the mixing ratio for drainage water with fresh water to maximize the Net Present Value (NPV) of the project. The model applies different mixing ratios for drainage water and fresh water to estimate the total volume of the mixed irrigation water. Any change in the mixing ratio affects the available water for the proposed irrigation project in terms of irrigation water quality and quantity. The economic return of the drainage water irrigation project is influenced by quality and quantity of the available irrigation water.

The model identifies and quantifies the impacts of the drainage water irrigation project. It converts those impacts into money, calculates its NPV and selects the mixing ratio with maximum NPV. Based on the selected mixing ratio, the model specifies the annual volume of drainage water and fresh water to be mixed and used in the suggested irrigation project.

The model was applied to evaluate the reuse of drainage water from Bahr Hadus drain to recover the shortage in the fresh irrigation water of Bahr Moius canal through Hanut pump station. The project area is located in Sharkia Governorate, East Delta of Egypt. The size of the study area is about 80000 feddan cultivated with different crops all over the year. The model suggested a seasonal mixing ratio instead of the fixed annual mixing ratio. The suggested mixing ratios will increase the NPV of the project by 14% over the project life span.

In this paper the sensitivity of the suggested procedure was tested against change in different economic parameters, water demand and availability. The tested parameters are prices of benefits and prices of costs. Also, the model was tested for the change in demand on drainage water and the availability of fresh water.

The results show that the change in benefit prices is significantly affects the model results more than the change in cost prices. The most sensitive parameter in the project benefits is the crop price. Also, the results show that the used volume of fresh water or drainage water is also affected dramatically with the decrease in the prices of costs or benefits rather than their increase.

Keywords water reuse, project economics, project design, irrigation, model sensitivity

Background

Egypt is one of the leading countries in the reuse of drainage water for irrigation. Annually, Egypt uses 88% of its available fresh water resources in the agricultural sector, a situation that has resulted in the national policy for the drainage water reuse.

The officially reused drainage water increased from 2.6 billion cubic meters per year in the 1980s to about 5.2 billion cubic meters per year in the early 2000s. El-

Ummum drain project in the Western part of the Delta (1 billion cubic meters per year) and El-Salam Canal Project (2 billion cubic meters per year) will bring the total reused drainage water in the Nile Delta by the year 2010 to about 8.2 billion cubic meters per year. This volume of drainage water is reused for irrigation after mixing with fresh water (Nile water) using a mixing ratio 1: 1 to reduce the irrigation water salinity to an acceptable limit.

Benefits of drainage water reuse in irrigation are expressed in agricultural production, the contribution of irrigation to aquifer recharge, saving in drainage water disposal cost and value of the saved fresh irrigation water.

At the same time drainage water irrigation may be hazardous to the environment, since this water contains pollutants such as salinity, pathogens, trace and heavy metals, nutrients and pesticides. The use of marginal quality water has the potential of causing serious problems of soil degradation and reduction in crop productivity because of irrigation water quality. Other problems such as human health hazards and quality degradation of groundwater are also involved.

Any decision making related to drainage water reuse should consider both aspects: benefits and hazards (costs). Adjusting the irrigation water quality based on the economic return using the mixing ratio can decrease hazards. Changing the mixing ratio of drainage water with fresh water will change the quality and quantity of the irrigation water and will affect the impacts of the irrigation project. The change in the project impacts will change the costs and benefits of the project. The optimal decision-making procedure aims at maximization of net national benefits, i.e., benefits minus costs and the value of environmental damage.

A model to maximize the economic return of the drainage water reuse in irrigation in Egypt was developed. The maximization criterion is the Net Present Value of the costs and benefits of drainage water irrigation project. The model uses different mixing ratios for drainage water and fresh water to estimate the total volume of the mixed irrigation water for the irrigation project. Changing the mixing ratio results in change in quality and quantity of the available water for the proposed irrigation project. Cost and benefit of the project is affected by the quality and quantity of the irrigation water

Sensitivity of the model was tested against changes in economic parameters, water availability and demand. The tested parameters are prices of benefits and prices of costs. Also, the model was tested for the change in demand on drainage water and the availability of fresh water.

The Model

The developed model assumes that the available volume of fresh water F is limited and less than the irrigation water requirements for the project area (El-Hawary, 2003). Part of the available fresh water F’, which is equal or less than F, is mixed with a volume of drainage water D' where D' ranges from zero to the maximum available volume of drainage water D. The model changes the values of D' and F' to maximize the Net Present Value (NPV) of benefits and costs for the irrigation project which uses drainage water mixed with fresh water for irrigation.

The objective function is

$$\text{Maximize} \sum_{t=0}^{T} \frac{1}{(1+r)^t}(B_t(F`,D`) - C_t(F`,D`)) \quad (1)$$

Subject to: $$B_t(F`,D`) = Y + W + R + V' \quad (2)$$

$$C_t(F`,D`) = C + S + H + T_r \quad (3)$$

$$F \geq F' \geq 0$$

$$D \geq D' \geq 0$$

Where B_t is the total annual benefits of the project in year t, C_t is the total annual costs of the project in year t, r is the discount rate and T is the project life. B_t and C_t are functions in the reused drainage water quantity and quality.

The annual project benefit B_t per unit area consists of the value of the agricultural output Y, the saved cost of drainage water disposal W, ground water recharge R due to irrigation in the project area, and value of the saved fresh water V' (El-Hawary, 2003)

The annual project cost per unit area C_t consists of the drainage water conveying cost to the project area C, the soil maintenance cost S, the cost of damage to health H, and the treatment cost of the pumped groundwater T_r (El-Hawary, 2003)

Case Study

1. The project area

Hanut pump station is one of the old stations for drainage water reuse in East Delta of Egypt. The main objective of Hanut project is to cover the shortage in irrigation water for the irrigated area from Bahr Moius and maintaining the agricultural productivity. According to the MWRI the maximum available fresh water F for irrigation in Bahr Moius upstream of Hanut feeding canal is 2634 m3/fed/year with an average salinity 300 ppm. The irrigated area after the mixing point is 82,738 fed., while the available drainage water for irrigation is 232 million m^3/year with an average salinity 900 ppm (table 1).

Currently, the project covers the shortage in irrigation water through pumping the drainage water from Bahr Hadus drain to Bahr Moius at Hanut. The model was applied to the project area to optimize the drainage water reuse in irrigation project. The model considered both the negative and positive impacts of the water reuse project.

2. Project Benefits

2.1. Value of agricultural production

When applying the model to the project area, it assumes that maize and berseem are the only crops cultivated in the project area.

Table 1 The details of the project area

Hanut Pump station and its served area			
Parameter	Unit	Value	
Project area	Fed	82,738	
The working hours	hour/year	4,500	
Discharge per unit	m^3/sec	5	
Number of pump units	Unit	4+1	
Max annual Discharge	m^3 /year	324,000,000	
Cost of the pump station	Million LE	22.5	
Working life of the pump station	Year	10	
Annual cost	Million LE	2.25	
Water quality parameters for SAR			
Na of the Drainage water	Meq/l	6.6	
Ca+Mg of the drainage water	Meq/l	6.4	
Na of the fresh water	Meq/l	1.4	
Ca+Mg of the fresh water	Meq/l	3.0	
Crop water requirements and water available			
	Unit	Maize	Berseem
Crop water requirement	m^3/fed	2700	3055
Max fresh water for each crop F	m^3/fed	1236	1398
Fresh water salinity	ppm	300	300
Max drainage water for irrigation D	m^3/fed	1958	1958

The optimum volume of irrigation water for maize is 2700 m3/fed. (DRI, 1997). Maize relative yield Y_{wm} with respect to the irrigation water volume per feddan $(D'+F')_m$ during the summer season is

$$Y_{wm} = 100 - 0.037*(2700-(D'+F')_m)$$

$$Y_s = 100 - b_1(SAL - a_1)$$

For irrigation water salinity, salt affected relative yield (Y_s) is estimated using the following equation
where a_1 is the salinity threshold expressed in mg/l; b_1 is the rate of yield decreasing due to irrigation water salinity expressed in % per mg/l; and SAL is the mean salinity of the irrigation water.

The salinity threshold for maize is 1 mmhos/cm.
For maize, the relative yield Y_{sm} with respect to irrigation water salinity

$$Y_{sm} = 100 - 18 * (SAL_m - 1)$$

$$Y_{rm} = Y_{sm} * Y_{wm}$$

The overall relative crop yield of maize Y_{rm} is obtained based on: Maize crop price in the project area is 100 LE/ardab and maize productivity is 20 ardab per fed. The cost of maize cultivation per season is 900 LE/fed.
Value of maize agricultural output

$$Y_m = 100*20*Y_{rm}/100-900$$

$$Y_m = 20\ Y_{rm}-900 \quad \text{LE/fed}$$

Berseem

The optimum irrigation water volume for berseem is 3055 m3/fed.
Berseem relative yield Y_{wb} with respect to the irrigation water volume per feddan $(D'+F')_b$ during the winter season

$$Y_{wb} = 100-0.033*(3055-(D'+F')_b)$$

The irrigation water salinity threshold for berseem is 1.6 mmhos/cm.
Berseem relative yield Y_{sb} with respect to irrigation water salinity

$$Y_{sb} = 100-12*(SAL_b-1.6)$$

$$Y_{rb} = Y_{sb} * Y_{wb}$$

The overall relative crop yield of berseem Y_{rb} is obtained based on: Berseem crop price in the project area is 820 LE/fed for each cut and the berseem is cut five times per season. The cost of berseem cultivation per season is 351 LE/fed.

Value of berseem agricultural output

$$Y_b = 820*5*Y_{rb}/100-351$$
$$= 41\ Y_{rb}-351 \quad \text{LE/fed} \qquad \text{II}$$

The annual Gross Margin per feddan in the project area is the summation of equations I and II.

2.2. Value of the aquifer recharge

Benefit to aquifer recharge R is the relevant value of the water contributed by irrigation to aquifer recharge. In neighbour countries to Egypt, irrigation recharge accounts for 36% of the applied irrigation water with the high irrigation efficiency (Haruvy, 1997b).
In Egypt where the irrigation efficiency is low, the contribution of irrigation to aquifer recharge is high.
The ground water recharge due to irrigation in the project area

$$= \alpha(F`+D`)$$

where α is the ratio of irrigation water that percolates to the aquifer (deep percolation).
If β is the unit price of the ground water, then
The ground water recharge = $\beta\alpha(F`+D`)$

The recharge value due to the drainage water reuse is

$$R = \beta \alpha D`$$

Assume α is 10% and β =0.2 LE/m3

Then R = 0.2*10/100*D'

R = 0.02 D' LE/fed

2.3. Saving in costs of drainage water disposal to the sea

The reduction in cost of sea disposal W is considered benefits since it is avoided when drainage water is used in irrigation downstream i.e. costs of drainage water disposal are added to get the net national benefit of the drainage water reuse.

According to Egyptian Public Authority for Drainage Projects, the annual cost of the drainage system is 40 million LE and the average annual drained water from the Delta is 14 billion m^3/year. The cost per m^3 is 0.03 LE/m^3.

The saving in cost of the drainage water disposal to the sea

W = 0.03 D'

2.4. Value of the saved fresh water

Reuse of the drainage water in irrigation will reduce the pressure on the fresh water resources. The saved water can be used in different purposes. The value of the saved fresh water V' is calculated based on the use of this water in irrigation in another area.

The saved volume of the fresh water = F-F'

Eldesukki, 1997 evaluated the value of the fresh water for different crops in East Delta as shown in table 2.

Table 2 Value of the fresh water for different crops in East Delta

Crop	Value (LE/m^3)
Wheat	0.31
Bean	0.64
Berseem	0.18
Cotton	0.53
Rice	0.39
Maize	0.20
Average	0.38

Then, value of the saved fresh irrigation water V` = 0.38 (F-F')

Summary of project benefits is shown in table 3.

3. Project Costs

3.1. Conveying costs

Conveying the drainage water of Bahr Hadus drain to Bahr Mouis canal was done by constructing a suitable pump station and carrier canal between the two water streams.

Table 3 Benefits of the drainage water reuse at Hanut area

Parameter	Unit	Maize	Berseem
Value of agricultural output			
Fresh water	m^3/fed	1236	1398
Volume of drainage water to be reused	m^3/fed	1464	1797
Irrigation water quantity = D+F	m^3/fed	2700	3195
Relative crop yield w.r.t. irrigation water quantity $Y_w = 100-b_2(X_o-X)$	%	100	105
Adjusted Y_w		100	100
Irrigation water salinity $EC=EC_1*F/(F+D)+EC_d*D/(D+F)$	ppm	625	637
Relative crop yield w.r.t. irrigation water salinity $Y'_s=100-b'(SAL'-a')$	%	100	100
Adjusted Y'_s		100	100
Overall relative crop yield=$Y_w * Y'_s$	%	100	100
Crop price	LE/unit	100	820
Crop cost	LE/fed	900	351
$Y = P_i Y_i (F'+D' , D'/F') - C_i$	LE/fed	1100	2929
Value of the Groundwater recharge			
Water price	LE/m3	0.20	0.20
Recharge ratio	%	10	10
Recharge benefit R=βaD'	LE/fed	29	36
Saving in drainage water disposal cost			
Drainage water disposal cost	LE/m3	0.03	0.03
Volume of drainage water to be reused	m^3/fed	1464	1797
Drainage water disposal cost W=□D'	LE/fed	44	54
Value of the saved fresh water			
Saved volume of fresh water (F-F')	m^3/fed	0	0
Fresh water value	LE/m3	0.38	0.38
Value of the saved water V'=□ (F-F')	LE/fed	0	0
Annual Benefits	LE/fed	1173	3019
Total annual benefits	LE/fed	4192	

The installation cost of the pumping station is 23 million LE. The installation cost can be expressed as a cost per unit volume of reused drainage water over the project life. Assuming an interest rate 12% and the working life for the station is 10 years, then the annual cost is 2.25 million LE. The annual operation and maintenance cost for the conveying system is assumed as 10 % of the installation cost.

The summation of both types of costs is the annual conveying cost.

The annual operation and maintenance cost = 0.10 * 23,000,000 =2,300,000 LE

The cost of conveying the drainage water to the project area per cubic meter is =(2,250,000 + 2,300,000) /324,000,000 = 0.01 LE/m^3

The conveying cost per fed C = 0.01 D'

3.2. Aquifer pollution

Damage to aquifer resulting from seepage of different pollutants from drainage water. The pollution can affect any current and future uses of the groundwater. The studies show that the annual groundwater pumping in the project area is 24 million m^3/year. To maintain the quality of the pumped groundwater, there will be an additional treatment cost to remove the pollutants from that water. The treatment cost T_r is a function in the volume of pollution reached the aquifer. Treatment of the reused drainage water as the source of groundwater pollution will save the quality of the groundwater. The ground water recharge due to drainage water reuse in irrigation in the project area

$$= \alpha D`$$

where α is the ratio of irrigation water that percolates to the aquifer (deep percolation). The required treatment cost T_r for reusing the volume of drainage water D'

$$T_r = \theta \alpha D'$$

θ is the treatment cost per unit volume =1 LE/m^3 and α is 10%, then the treatment cost for the groundwater water

T_r = 0.1 D' LE/fed.

3.3. Health damage

According to the Egyptian records the annual death is 400,000 in all Egypt which mean 0.6% of the population (CAPMS, 2003).

The health damage occurs mainly in the farmers. The model assumes one farmer/feddan, i.e. the number of farmers equals the irrigated area in feddan. The cost of health damage calculated based on a population of 82,738 in the project area and an increase in the probability of death by 0.002 based on the previous studies on the health impacts of water pollution (Giraldez & Fox, 1995 and Haruvy 1997a), the average value for life is assumed as LE100,000.

Health damage H = Reused drainage water D' * (Increase in the probability of death * Population * Value for life / Maximum reused drainage water D) LE/m^3

= D' * (0.002 * 82,738 *100,000 / 324,000,000)

Health damage cost H = 0.05 D' LE/fed.

3.4. Soil treatment cost

The soil treatment cost S is a function in SAR of the irrigation water. Assuming a linear relationship between the treatment cost and the increase in SAR of the irrigation water, then

Annual soil treatment cost S

= Reclamation Cost of soil /Unit SAR of the soil * ($SAR - SAR_o$)

Actual SAR is the resultant of mixing the fresh water F' and the drainage water D' based on the content of both from Ca, Mg and Na and the ratio of each type of water, which means

$(Ca + Mg)_m = D'/(D'+F') * (Ca + Mg)_D + F'/(D'+F') * (Ca + Mg)_F$

$Na_m = D'/(D'+F') * Na_D + F'/(D'+F') * Na_F$

then Actual SAR = $Na_m / \{(Mg+Ca)_m/2\}$^0.5

Assuming that a gypsum requirement is one ton per feddan for each unit increase in SAR of irrigation water. This amount is added each two years i.e. half ton per feddan per year for each unit increase in SAR of irrigation water. Adding half ton to one feddan will cost 10 LE i.e. the cost of soil reclamation would be 10 LE/feddan per unit increase in SAR of irrigation water. In EL-Sharkia Governorate the safe SAR_o for the irrigation water is 3. Then

S=10(SAR- 3) LE/fed

Details of different cost items are shown in table 4.

Table 4 Costs of the drainage water reuse at Hanut area

Parameter	Unit	Maize	Berseem
Drainage water conveying costs			
Conveying cost = g D'	LE/m3	0.01	0.01
Volume of drainage water to be reused	m^3/fed	1958	1958
Conveying cost C=0.1 D'	LE/fed	14	14
Aquifer pollution cost			
Treatment cost per unit volume of drainage water	LE/m3	1.0	1.0
Volume of drainage water to be reused	m^3/fed	1958	1958
Treatment cost for the groundwater T_r=0.1 D'	LE	196	196
Cost of Health damage[1]			
Health cost	LE/m3	0.05	0.05
Volume of drainage water to be reused	m^3/fed	1958	1958
Health damage	LE/fed	98	98
Soil treatment cost			
Sodium Adsorption Ratio of the fresh water SAR_f		1.2	1.2
Sodium Adsorption Ration for the drainage water SAR_d		3.7	3.7
Cost of soil reclamation	LE/fed	20	20
Limit of SAR for soil treatment		3	3
new SAR of soil $SAR=SAR_f * F'/(F'+D') + SAR_d * D'/(F'+D')$		3.13	2.95
		3.13	3.00
Soil treatment cost $S= \lambda (SAR - SAR_0)$	LE/fed	3	0
Annual cost	LE/fed	310	307
Total annual cost		617	

[1] The cost of health damage calculated based on a population of 82,738 in the project area and an increase in the probability of death by 0.002 and the average value for life is assumed as LE.100.000. i.e. mortality cost = 0.05 LE/m3 of the drainage water

4. Economic Analysis

Once the cost and benefit of the suggested project are specified, the economic analysis can be carried out. The additional items, which are required for the economic analysis, are: project span (life) and interest rate. The project life is considered 30 years and the interest rate is considered 12%.

For each alternative (F`& D`), NPV equals the difference between the present value of the benefits PV(B) and the present value of the costs PV(C):

NPV = PV (B) - PV(C)

The summation of the PV of the Net Benefits (NB) is the Net Present Value (NPV) of the irrigation project, i.e.

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = (B_o - C_o) + \frac{(B_1 - C_1)}{(1+r)} + \frac{(B_2 - C_2)}{(1+r)^2} + \ldots\ldots\ldots\frac{(B_T - C_T)}{(1+r)^T}$$

Where B_t and C_t denote the benefits and costs in year t, r is the discount rate (12%) and T is the project life (30 years).

2.5. Design Selection

The model uses the electronic spreadsheet to reach the mixing ratio of fresh water with drainage water that maximize the net present value NPV of the irrigation project.

From the results of the economic analysis, for maize crop the fresh water ratio is 46% and the drainage water ratio is 54% with annual B-C equal 943 LE/Fed. The fresh water ratio for berseem crop is 36% and its drainage water ratio is 64% with annual B-C equals 2,766 LE/Fed. The NPV over the project life is 30,262 LE/Fed (table 5).

Table 5 Summary of results for the drainage water reuse at Hanut area

Parameter	Unit	Maize	Berseem
Annual benefits B	LE/fed	1301	3073
Annual cots C	LE/fed	310	307
B-C	LE/fed	991	2,766
Project life	Years	30	30
Interest rate	%	12	12
NPV per crop	LE/fed	7,984	22,278
NPV	LE/fed	30,262	

Model Sensitivity

1. Sensitivity of the NPV to changes in prices of cost or benefit

The impact of change in benefit and cost prices on the model results were evaluated. All benefit prices were increased by 100% and 200%, and decreased by 25% and 40% from the original prices while the cost prices were remained constant. In another step, cost prices were increased by 100% and 200%, and decreased by 50% and 75% keeping benefit prices unchanged. The results showed that the change in benefit prices is highly affect the model results (NPV) more than the change in cost prices (Figure 1). The prices of the benefits should be very accurate to have a good result from the model.

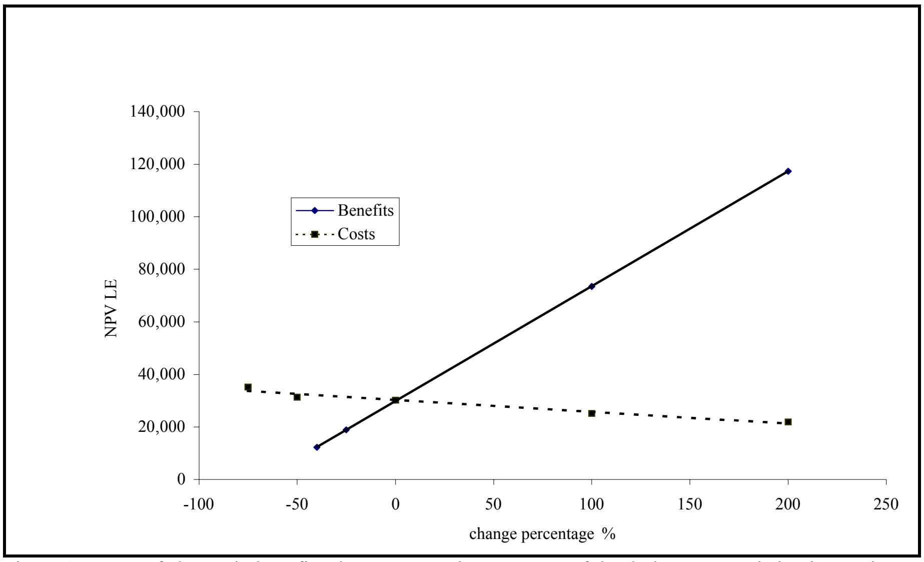

Figure 1 Impact of change in benefit prices or cost prices on NPV of the drainage water irrigation project

2. Impact of the change in prices of benefit parameters on the NPV

The model results were evaluated for the change in benefits prices i.e. value of the agricultural output Y, the saved cost of drainage water disposal W, ground water recharge R due to irrigation in the project area, and value of the saved fresh water V'.
Each benefit price was increased by 100% and 200% and decreased by 25% and 40% from its original price while all other prices of benefits and costs were remained constant. Regarding the crop benefits two cases were considered; (i) the crop price changes without any change in the crop cost, and (ii) the crop price and its cost change with the same amount. The results showed that the change in the crop price is the pioneer in affecting the NPV of the drainage water reuse project (Figure 2). Its effect is remaining with the change in crop cost. Other parameters of benefit have a negligible effect on the NPV of the project.

3. Impact of change in benefit and cost prices on the used volume of water in irrigation

The results of the model showed that the used volumes of both types of water are affected too much by the change in cost or benefit prices.

3.1. Volume of Drainage water D’

The relation between D’ and change in prices is nonlinear. As the prices of benefits increase, the demand for D’ also increases up to the optimum D’ where the crop water requirements is fully covered and the highest crop yield reached. Any increase in the prices of benefits after the optimum D’ decreases the demand for D’ as the resulted benefits are smaller than the costs (Figure 3). The demand for D’ is more sensitive for the decrease in the prices of benefits rather than their increase. Similar, any change in costs affects the reused volume of drainage water D’ but D’ is affected by the change in benefits more the change in costs.

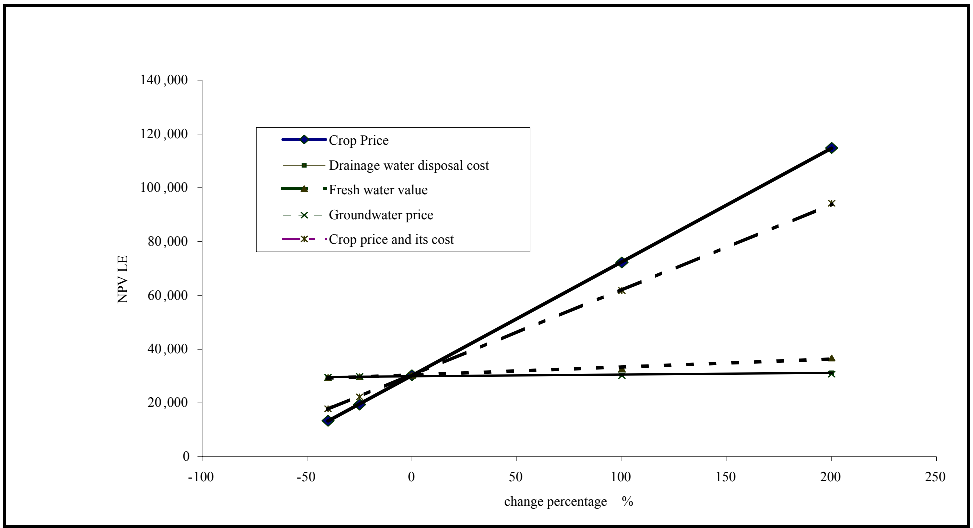

Figure 2 Impact of change in the prices of benefit parameters on NPV of the drainage water irrigation project

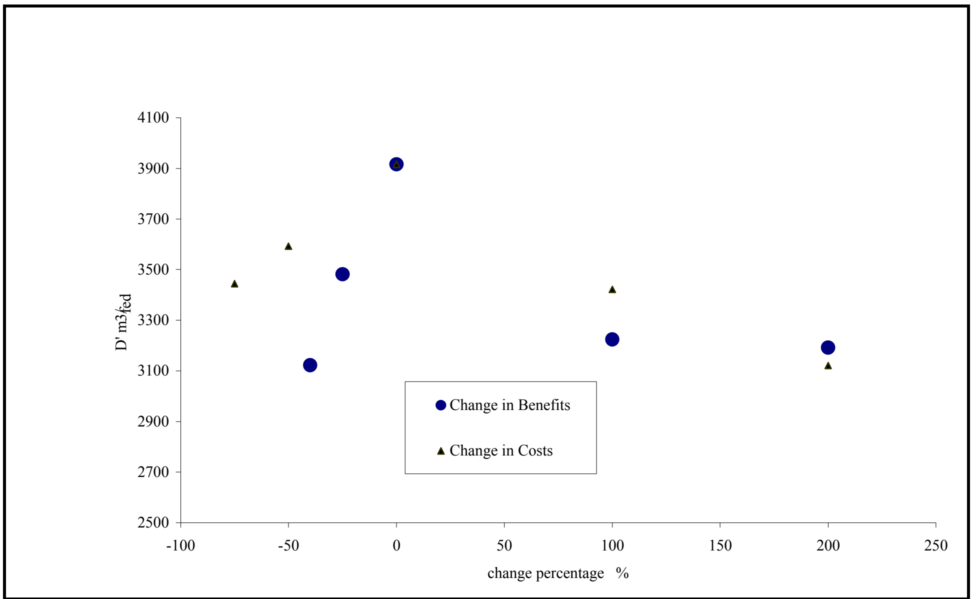

Figure 3 Impact of change in benefit prices or cost prices on the reused volume of drainage water in irrigation

3.2. Volume of Fresh water F'

Change in the prices of benefits or costs affect the demand for fresh water F' (Figure 4). However, the decrease in the prices of benefits or costs affects F' faster than their increase.

The relation between the demand for F' and change in prices is nonlinear. As the prices of benefits increase, the demand for F' decreased up to the optimum F'. After that, any increase in the prices of benefits increases the demand for F' as the resulted benefits are not accompanied by any additional costs. This increase in demand for F' is limited by the available fresh water. The change in cost has the same impact on the demand for F'.

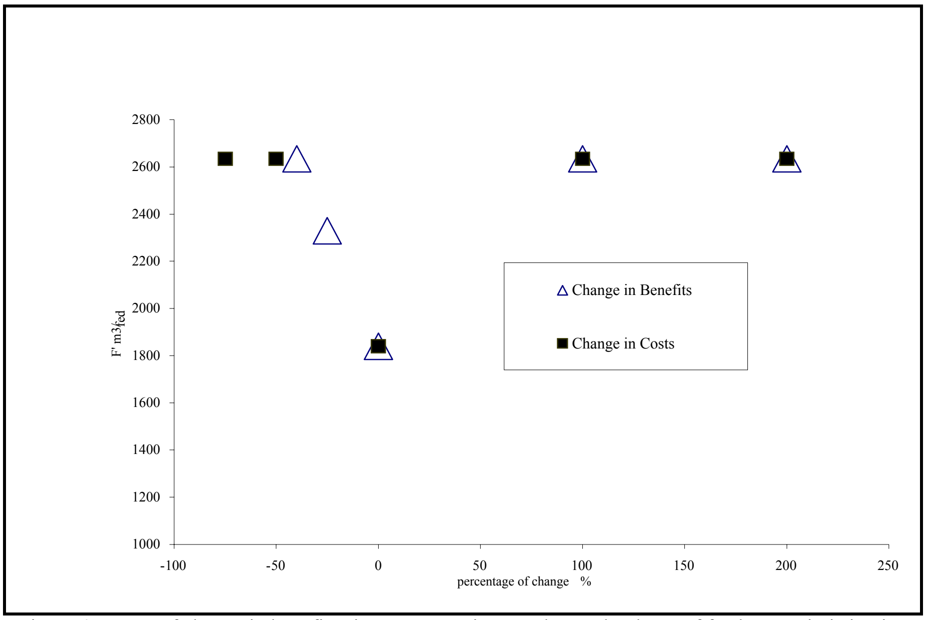

Figure 4 Impact of change in benefit prices or cost prices on the used volume of fresh water in irrigation

Summary and Conclusions

A model for maximizing the economic return of drainage water reuse in irrigation was developed. It selects the mixing ratio for drainage water with fresh water to maximize the NPV of the project. The model applies different mixing ratios for drainage water and fresh water to estimate the total volume of the mixed irrigation water. Any change in the mixing ratio affects the available water for the proposed irrigation project in terms of irrigation water quality and quantity. The economic return of the drainage water reuse project is influenced by quality and quantity of the available irrigation water.

The model identifies and quantifies the impacts of the drainage water irrigation project. It converts those impacts into money, calculates its NPV and selects the mixing ratio with maximum NPV. Based on the selected mixing ratio, the model specifies the annual volume of drainage water and fresh water to be mixed and used in the suggested irrigation project.

The model was applied to evaluate the reuse of drainage water from Bahr Hadus drain, East Delta of Egypt, to recover the shortage in the fresh irrigation water of Bahr Moius canal through Hanut pump station. The model suggested a seasonal mixing ratio instead of the fixed annual mixing ratio. The suggested mixing ratios will increase the NPV of the project by 14% over the project life span.

The sensitivity of the model was tested against changes in different economic parameters, water availability and demand. The tested parameters are changes in prices of benefits or costs. Also, the model was tested for the change in demand on drainage water and the availability of fresh water,

The results show that the change in benefit prices is highly affects the model results more than the change in cost prices. The most sensitive parameter in the project benefits is the crop price. The results of the model show that the used volume of fresh water or drainage water is also affected too much with the change in the prices of costs or benefits.

References

DRI (Drainage Research Institute). 1997. Water requirements of major crops in the Nile Delta, Drainage Research Institute, Cairo, Egypt.

Eldesukki, H. 1997. Economics of drainage water reuse for irrigation in the Nile Delta, PhD thesis, Cairo Univ., Egypt.

El-Hawary, A. 2003. Study of the Optimum Management Strategy for the Reuse of Agricultural Drainage Water in Irrigation in Egypt, PhD thesis, Ain Shams Univ., Cairo, Egypt.

Giraldez, C. and G. Fox. 1995. An Economic Analysis of Groundwater Contamination from Agricultural Nitrate Emissions in Southern Ontario, Canadian Journal of Agricultural Economics. 43(3): 387-402.

Haruvy, N., 1997a. Agricultural reuse of wastewater: nation-wide cost-benefit analysis, Agriculture ecosystems & environment, vol. 66.

Haruvy, N., 1997b. Wastewater irrigation decision-making: farm sector interests versus the nation’s, International water and irrigation review, vol. 17, no. 4.

نظام الإدارة الأمثل لإعادة إستخدام مياه الصرف في الري: آختبار حساسية النظام

أحمد محمد الهوارى

معهد بحوث الصرف – المركز القومي لبحوث المياه – القاهرة – مصر

تعتبر مياه الصرف مصدر له قيمته للإستخدام في الزراعة خصوصا في المناطق الجافة وشبه الجافة ومن أهم فوائد الري بهذه المياه هو توفير مياه إضافية مما يعنى زيادة الرقعة الزراعية وبالتالى الإنتاجية الزراعية، مع إمكانية زيادة التغذية للخزان الجوفي والوفر في تكاليف التخلص من مياه الصرف. ومن جهة أخرى فإن لهذه المياه آثارها السلبية التى تؤدى لتدهور التربة وتلوث الخزان الجوفي وإنتشار الأمراض بالإضافة لتكلفة نقل هذه المياه لمواقع إستخدامهـــا.

لقد جرى العرف فـــي مصر على أن يتـــم خلط مياه الصرف مع المياه العذبة بنسبة 1 : 1 قبل إستخدامها في الـــري بدون إعتبار للآثار الممكن حدوثها من جراء تثبيت هذه النسبة فى الظروف المختلفة . ويقدم هذا البحث نموذج لتعظيم الإستفادة من مياه الصرف المخلوطة بنسب مختلفة مع المياه العذبة فى أغراض الرى بناء على العائد الإقتصادى الناتج عن إستخدامها ويتم ذلك بافتراض نسب خلط مختلفة لمياه الصرف مع المياه العذبة ثم حساب العائد الإقتصادى الناتج مع مراعاة الجوانب الإيجابية والسلبية والتكاليف اللازمة لكل نسبة خلط على مدى عمر المشروع وآختيار أفضلها فى صافى العائد الإقتصادى . وقد تم آختبار حساسية النموذج للتغير فى المدخلات مثل التغير فى أسعار تكلفة أو عائدات المشروع وكذلك التغير فى نوعية وكمية المياه المستخدمة وتأثير ذلك على تصميم المشروع والعائد الإقتصادى منه.

الكلمات المفتاحية : مياه الصرف, العائد الإقتصادى, تصميم المشروع, الـــري, الزراعة, حساسية النموذج