OPTIMUM CROPPING PATTERNS OF EL- BEHAIRA GOVERNORATE (WINTER SEASON)

G. A. Sharaf [1], Azza Hassan [2] and H. H. Mohamed [3]

ABSTRACT

Two fundamental factors contribute to Egypt's food security challenge: the rapidly growing population and the limited availability of agricultural land. Expanding agricultural land in Egypt is tightly constrained by the availability of water. This research aimed to develop an optimization model for the determination of cropping patterns to get the maximum profits of EL- Behaira governorate in winter season. Decision variables are the governorate total cultivated area, soil type, soil salinity, available water, potential crop yield, crop tolerance to salinity, irrigation system efficiency and irrigation water salinity. The objective function of the model is based on crop-salinity production function, crop value and production total costs. The model is solved using solver application of Microsoft Excel. The model gives the optimal distribution of crops area, water and profits. Four scenarios were introduced. Two represent un-restricted solutions; means that the objective function based on the maximum income as a function of crop value, tolerance to salinity and available water only. The other two scenarios take into account local market requirements and food security. Seven winter crops were selected; clover, sugar beet, wheat, barley, tomatoes and flax. These crops represent 97.5 % of crop cultivated area in El-Behaira governorate. The total available water in the winter season is 1.236 billion m^3. The total crop area of the governorate is 592,771 Feddan (248,963 hectare). In the first un-restricted solution (URS1) all crops were assumed to be irrigated by the surface irrigation system. The optimum solution was to cultivate only three crops; barley, clover and wheat. The net return was L.E. 1.72 billion, 45.92 % of the income related to barely follow by clover 38.47% and wheat 15.61%.

1- Professor of Ag. En., Fac. of Ag. Saba – Basha Alex Uni

2- Senior researcher, Ag. En. Research Inst. Cairo – Egypt.

3- Lecturer of Ag. En., Soil Dept., Saba - Basha Alex. Uni

At the second un-restricted solution (URS2) tomato irrigated by trickle, sugar beet irrigated by sprinkler and the rest of crops by surface irrigation. The maximum net return was 2,971,398,501 L.E.; 85% form tomato and 15% form clover, which saving 5% of the available water. The first restricted solution. The limited cultivated area of wheat, was between 30 to 60 %, barley and clover were between 5 to 10%, while bean, tomato, sugar beet and flax were between 3 to 5%. The first restricted solution (RS1) resulted in L.E. 1.64 billion.

The cultivated areas were 15, 3, 57, 14.04, 3, 4.96 and 3% for clover, sugar beet, wheat, barley, bean, tomato and flax, respectively. The net income for the second restricted solution (RS2) was 1,841,584,834 L.E.,which distributed as 29.3, 10.18, 43.57, 2.19, 1.28, 17.91 and 1.4 % for clover, sugar beet, wheat, barley, bean, tomato and flax respectively. Sensitivity analysis for irrigation efficiency, available water and irrigation water salinity were examined. The results indicated that net income increased proportional with the increase of irrigation efficiency and available water while decreased inversely with the increase of irrigation water salinity.

INTRODUCTION

Agriculture is considered to be the major economic activity in Egypt which lags behind in achieving self-sufficiency in strategic food commodities. In 2007, the self-sufficiency ratios of wheat, maize and bean reached 54, 53 and 52% respectively (Ministry of Agriculture and Land Reclamation (MALR), 2009-2010). In the same year imports of agricultural commodities reached USD 8.66 billion, which representing almost 18% of the total imports. Egypt was the world's top bean importer in 2009, the fourth largest importer of wheat, and the seventh top importer of both maize and palm oil (FAO, 2011). Crop planning involves two distinct policy tools; namely crop rotation and crop mix. Crop rotation involves the decision to plant a sequence of crops in successive years on the same piece of land. Crop mix, on the other hand, is a crop planning system that involves "more than one crop in the same year on the total land (Mohamad and Said, 2011). The increase of soil deterioration and irrigation water salinity in arid climate territories need for a rational use of the resource. Knowledge of production function related the actual yield to crop tolerance of salinity and soil salinity is the key for selection of most suitable management for crop mix or crop pattern. These cropping patterns can be attained through the use of optimization modes (Chavez-Morales et al., 1992). The models can be linear or nonlinear. Although linear optimization models are used more frequently, they required that both objective function and constraint be linear. Nonlinear optimization models do not have the linearity limitations (Hillier and Lieberman, 1980). Linear Programming (LP) is most widely used technique to solve optimization problems that seek to determine the optimal crop mix, either by maximizing return or minimizing costs, subject to a set of constraints. Henderson (1959) was among the earliest studies that applied LP to determine the optimum land utilizations. Several studies on developing countries applied LP to determine the optimum crop mix. Sarker et al., (1997) developed a model for annual land allocation among alternative crops in Bangladesh that seeks to determine the area to be used for different crops. The objective was to maximize the contribution from cropping and food importation. Hassan et al. (2005) applied a profit maximization LP model to solve for the optimum cropping pattern in different provinces in Pakistan. Singh et al. (2001) formulated a LP model to determine the optimum cropping patter for different farms in India, with the objective of maximizing net return. Recently, Mohamad and Said (2011) utilized LP to determine the optimal crop mix for Malaysia for a planning horizon of 12 months.

Hanna (1970) employed LP to determine the optimum cropping pattern for Dakahlya governorate, while Siam (1973) applied LP to develop future crop production plans for each governorate. The objective function in both studies was to maximize net return from the proposed pattern. Later, Mohamad (1992); El Kheshen (1992); Hussein and Eita (2001); and Ali (2003) also solved for the optimal crop mix for specific governorates regions in Egypt using the LP. The models employed maximizes either net return per feddan to farmers or return per unit of irrigation water; subject to a set of constraints including cultivated areas, water resources and other management constraints. A recent study by Enaber et al. (2009) employed LP to determine the optimum crop pattern for Egypt with the objective of maximizing net return per feddan in addition to maximizing net return per unit of irrigation water. A study by Ismail and Ata (2005) modeled the optimum crop mix for Egypt using a non-linear objective function to maximize net profit which subject to a number of linear constraints on land, water resources, labor and capital. The "Multiple Criteria Decision Making" (MCDM) is another approach used in literature on agricultural planning. MCDM applications are considered more superior over the LP modeling, as they allow for tackling multiple objectives. In agricultural planning, determining the optimal allocation of land requires decision makers to consider a number of socio-economic objectives, including the availability of resources. Among the mathematical tools of MCDM is the multi objective linear programming model (MOLP). MOLP generates a set of efficient solutions, also called "non-dominated or pareto-optimal solutions. Piech and Rehman, (1993). Siskos et al. (1994) applied a multi-objective linear programming model to determine the optimum land allocation among different crops in a Tunisian region. Aly et al., (2007) used a NLP model to determine the optimal cropping pattern for desert lands in Egypt that depends on ground water by maximizing the net revenue per unit of irrigation water. The purpose of this paper is to develop a nonlinear programming model that allocates optimally available resources and furnishing an optimal cropping pattern in the largest Egyptian agricultural governorate (EL-Behira). The area distributed will be used to maximize the total net return. The decisions will conditioned by the available water, land and their salinities, crop net return and efficiency of the irrigation system.

MATERIALS AND METHOD

Salinity hazard

Salinity affects plant growth resulting in lower crop yields and reduced agricultural production. As soil salinity increases, plant hardly absorb water from the soil and disturb the balance of plant nutrients in the soil. Salinity may also affect the physical and chemical properties of soil, resulting in surface soil compaction and erosion. High levels of salt can dehydrate soil bacteria and fungi and reduce soil health, which depends on good microbial activity for the formation of organic matter and nutrient recycling; these effects resulted in reduction in crop yield.

Yield -Salinity relationship

A widely practiced approach for predicting the reduction in crop yield due to salinity has been described by the FAO Irrigation and Drainage Paper No29 (Ayers and Westcot, 1985). The approach presumes that, under optimum management conditions, crop yields remain at potential levels until a specific, threshold electrical conductivity of the soil water solution is reached. When salinity increases beyond this threshold, crop yields are presumed to decrease linearly in proportion to the increase in salinity (Allen et al., 1989).

$$\frac{Y_a}{Y_m} = 1 - (EC_e - EC_{e\ threshold})\frac{b}{100} \qquad (1)$$

where:

Y_a Actual crop yield

Y_m maximum expected crop yield when $EC_e < EC_{e\ threshold}$

EC_e electrical conductivity of the saturation extract for the root zone [dS/ m]

$EC_{e\ threshold}$ electrical conductivity of the saturation extract at the threshold of EC_e when crop yield first reduces below Ym [dS /m]

b reduction in yield per increase in EC_e [%/(dS /m)]

Salts are added to the soil in each irrigation. These salts will reduce crop yield if they accumulate in the rooting depth. In order to prevent the built up of salinity, leaching requirement (LR) will be:

$$LR = \frac{EC_w}{5\,EC_e - EC_w}\ \textit{For surface and sprinkler systems} \qquad (2)$$

$$LR = \frac{EC_w}{2\,Max\,EC_e}\ \textit{For trickle systems} \qquad (3)$$

Where:

EC_w Salinity of the applied irrigation water (dS/m)

EC_e Average soil salinity tolerated by the crop (dS/m)

$MaxEC_e$ Maximum crop soil salinity tolerated (dS/m),where the yield is zero

Optimization

A nonlinear programming model will be formulating to maximize profit subject to restrictions of water availability, soil type and salinity. The objective function of the model can be represented as:

Maximize :

$$P_r = \sum_{i=1}^{n}\sum_{j=1}^{m} A_{ij}\,(P_j\ Y_{ij} - C_{ij}) \qquad (4)$$

Where:

P_r Profit (L.E.)

P_j Price received from crop j(L.E/ton)

A_{ij} Cultivated area (feddan)

Y_{ij} Yield per unit area (ton/feddan)

C_{ij} Total cost per unit area (L.E./feddan)

i Integer number representing the soil type (1, 2, 3 … n=4)

j Integer number representing the crop (1, 2 , 3, …….m=7)

Substituting of Eq.(1) into Eq.(4) gives:

$$P_r = \sum_{i=1}^{n}\sum_{j=1}^{m} A_{ij}\left[\left[P_j . Y_m\ \left(1 - (ECe_i - EC_{ethreshods_j})\frac{b_j}{100}\right)\right] - C_{ij}\right] \qquad (5)$$

Cost C_{ij} subdivided into: land preparation, seedling and planting, irrigation, fertilization, transportation, other expenses.

The constraints are based of soil type, salinity, availability of resources and market considerations as follows:

1- Soil availability as

$$\sum_{j=1}^{m} A_{ij} \le A_i \qquad \sum_{i}^{n}\sum_{j}^{m} A_{ij} \le A_t \qquad A_t \le \sum_{i=1}^{n} A_i \qquad (6)$$

2 – Water availability

$$\sum_{i=1}^{n}\sum_{j=1}^{m} 2.4\left[\frac{In_{ij}}{(1 - LR_{ij})\ E_{ij}}\right] A_{ij} \le W_t \qquad (7)$$

Where:

In_{ij} Net irrigation requirement for crop j (m^3/ feddan.)

LR_{ij} Leaching requirements for crop j in soil i

E_{ij} Application efficiency of crop j in soil i

W_t Total available water m^3

At Total available land (feddan)

3 – Agronomic management

Some management and market considerations restrict even further the model variables. For example, crop rotation, market limitations, and agronomic management limit the maximum and or the minimum area cultivated with specific crop. The cultivated area could also be limited to a specific ratio of the available water to each or a certain crop. Mathematically, this restriction can be expressed as:

$$A_t\, AC_{j-min} \le \sum_{i=1}^{n} A_{ij} \le AC_{j-max}\, A_t \qquad (8)$$

$$W_t\, CW_{j-min} \le \sum_{i=1}^{n} W_{ij} \le CW_{j-max}\, W_t \qquad (9)$$

Where:

A_{ij} Area cultivated by crop j in soil i

W_{ij} Irrigation water for crop j in soil i

AC_{j-min} Minimum value of cultivated area of crop j

AC_{j-max} Maximum value of cultivated area of crop j

CW_{j-min} Minimum value of available water to cultivate crop j

$CWj\text{-}_{max}$ Maximum value of available water to cultivate crop j

Resources

Seven winter crops were selected for crop pattern that represents 97.5% of the total cultivated area of the governorate (About 592,771 feddan according to Environmental Description Report of El-Behaira Governorate 2008). The crops were clover, sugar beet, wheat, barley, bean, tomato and flax. Potential Yield per feddan and crop value presented in Table (1) includes main crop value, straw crop value (Data cited from statistics of prices, costs, and net returns report of the economic affairs sector 2009-2010, Ministry of Agriculture and Land Reclamation). Irrigation water quantity for optimum crop yield and Soil types & salinity are shown in Tables (2) and (3) respectively, which had taken from the final report of Drainage Water Irrigation Project (DWIP), (1997). The area cultivated by each of these crops in 2010 is presented in

Table (3). The same table showed that the threshold value of soil salinity that the crop yields start to be declined and the rate of declination (b), in addition to the crop salt tolerance. Ratings to salinity are: T = tolerant, MT= moderately tolerant, MS= moderately sensitive and S= sensitive. Table (4) showed that the average production cost per feddan includes land preparation, seedling and planting, irrigation, fertilization, transportation, other expenses rent and the net return of each of the selected crops.

Table(1): Potential yield , prices and irrigation quantities for optimum crop yield.

Crop	Yield		Price		Value (L.E./feddan)
	Main	Secondary	Main	Secondary	
Clover	32.00 (Ton/fedd.)	-	8480 (L.E./fedd.)	-	8480
Sugar beet	17.65 (Ton/fedd.)	17.65 (Heml/fedd.)	263 (L.E./Ton)	45 (L.E./Heml)	5436
Wheat	17.45 (Ardab/fedd.)	12 (Heml/fedd.)	260 (L.E./ Ardab)	110 (L.E./Heml	5857
Barley	13.22 (Ardab/fedd)	7 (Heml/fedd.)	305 (L.E./Ardab)	100 (L.E./Heml)	4732
Bean	8.58 (Ardab/fedd.)	7.5 (Heml/fedd.)	567 (L.E./Ardab)	65 (L.E./Heml)	5352
Tomato	12.54 (Ton/fedd.)	-	680 (L.E./Ton)	-	8525
Flax	4.60 (Ton/fedd.)	4.85 (Ardab/fedd.)	705 (L.E./ Ton)	530 (L.E/Ardab)	5813

Table (2): Soil type and salinity of EL-Behaia governorate.

Soil texture	Average Area (Feddan)	Area, %	Average soil salinity (dS/m)
Clay (C)	88916	15	5.19
silt clay (S.C)	207470	35	3.93
clay loam (C.L)	118554	20	4.15
silt clay loam (S.C.L)	59277	10	4.61
loamy fine sand (L.F.S)	118554	20	3.62

Table (3): Salinity characteristics of crop pattern of EL-Behaira governorate

Crop	$EC_{threshold}$ (dS/m)	B (%/(dS/m)	Rating to Salinity	Area, %	Irrigation Water m^3/season
Clover	1.5	7	MS	29.73	3055
Sugar beat	7	5.9	T	7.02	2200
Wheat	8.6	3	T	50.66	1600
Barley	8	5	T	0.49	1400
Bean	1.6	9	S	6.92	1350
Flax	1.7	12	MS	2.25	2800
Tomato	2.5	9	MS	0.47	1070

Table (4): Cost of the individual operation of crop production and the net return(L.E./feddan)

Crop	Land Preparation	Seeding & Planting	Irrigation	Fertilization	Weeding	Pest Control	Harvesting	Transportation	Other expenses	Rent	Total Cost (L.E./fedd.)	Net Return (L.E./ fedd)
Clover	105	220	165	215	-	-	-	-	65	1500	2270	6210
Sugar Beet	170	225	162	405	230	240	145	125	136	1200	3038	2398
Wheat	80	220	204	515	95	150	400	100	176	1500	3440	2417
Barley	80	120	102	365	-	-	310	100	130	1250	2457	2275
Bean	160	418	102	460	65	170	290	75	174	1500	3414	1938
Tomato	140	505	204	1030	200	320	250	120	251	1000	4020	4505
Flax	80	380	164	415	65	-	210	90	125	1500	3029	2784

RESULTS AND DISCUSSION

The model result presented in four scenarios. The first scenario based on the maximum return regardless of the needs of the domestic market. The second takes into account the market and food security. The third is designed to maximize the return where tomato applied trickle irrigation and sugar beet applied sprinkler and the rest of crops used the surface systems. The fourth applied the previous rule taking into account the domestic consumption and food security.

The first scenario:

For maximizing the net return depends on selecting the crop to be cultivated in a certain area depends on crop net price, tolerance sensitivity to soil salinity and irrigation water salinity that reduce the yield and increase irrigation water by adding leaching fraction to stop crop yield reduction, and the availability of water. For the highest net return regardless to the market considerations, the model found that planting three crops is sufficient to fulfill the objective function. This solution called un-restricted solution 1 (URS1). The net return was 1,717,136,466 L.E. Result presented in Table (5) showed that 45.92 % of the income related to barley followed by clover 38.47% and wheat 15.61%. Although, the net income of the clover is the highest among the other crops (under the salinity condition of the soil about 4800 L.E/fed.) as shown in Table (6), the cultivated area is about 22.5 %. This is because it needs 4070 m^3/fed. of irrigation water includes about 25% leaching fraction. Meanwhile, the wheat needs 1660 m^3/fed. of irrigation water includes 4% leaching fraction and the crop value was 2416 L.E./fed. The Barley was the lowest crop in water consumption about 1457 L.E., that includes leaching fraction 3.9 % and the crop net income was 2264 L.E./fed. This remark may indicate that the water is the key factor in maximizing the income. To confirm the previous result, the model was run after reducing the available water by 20 %. The results showed that the clover cultivated area reduced to be 5.95% and both wheat and barley cultivated areas increased to 27.4% and 66.7% respectively.

Table (5): Results of un-restricted solution for crop pattern and their shares in area, net income and water use.

Crop	Soil type	Area		Net income		Water used	
		Feddan	%	L.E	%	m^3	%
Clover	(C)	118,554	20	588,096,171	34.25	482,910,775	39.07
	(S.C.L)	15,185	2.56	72,531,033	4.22	61,852,792	5
Total		133,739	22.56	660,627,204	38.47	544,763,566	44.07
Wheat	(S.C)	31,582	5.33	76,334,509	4.45	52,426,680	4.24
	(S.C.L)	63,176	10.66	152,695,341	8.89	104,871,438	8.48
	(L.F.S)	16,136	2.72	38,985,097	2.27	26,786,118	2.17
Total		110,894	18.71	268,014,948	15.61	184,084,237	14.89
Barley	(S.C)	86,972	14.67	196,999,966	11.47	126,696,849	10.25
	(C.L)	59,277	10	134,268,559	7.82	86,352,316	6.99
	(S.C.L)	129,109	21.78	292,445,872	17.03	188,081,100	15.22
	(L.F.S)	72,779	12.28	164,779,917	9.6	106,021,933	8.58
Total		348,138	58.73	788,494,314	45.92	507,152,197	41.03
Summation		592,771	100	1,717,136,466	100	1,236,000,000	100

Meanwhile, the net income decreased by 14.8%. In further reduction in water to 60% of the total available water, the results indicated that 81.51% of the total cultivated area will be only planted with 31.29 % wheat and 50.22 % with barley and the total income decreased by 34.63% from the maximum. In case of increasing the available water by 20%, the clover cultivated area increased to 38.07% while wheat and barley areas became 24.22 and 37.71% respectively. The total net income increased by 17.74 %. Results of these analyses are presented in Table. (7).

Table (6): Model results of yield, income and irrigation water under salinity condition

Crop	Soil type	Yield Ton/fedd	Net income L.E/fedd.	Leaching %	Total Irrigation water need m^3/fedd.	Salinity Tolerance
Clover	(C)	27.25	4961	25	4073	MT
	(S.C.L)	26.56	4777			
Wheat	(S.C)	5.69	2417	3.6	1660	T
	(S.C.L)	5.72	2417			
	(L.F.S)	5.53	2416			
Barley	(S.C)	3.57	2265	3.9	1457	T
	(C.L)	3.50	2265			
	(S.C.L)	3.60	2265			
	(L.F.S)	3.56	2264			

Table (7): Effect of available water on crop production.

Ava Water %	Crop	Area		Net income		Water use	
		Feddan	%	L.E	%	m^3	%
60	Wheat	185,495	31.29	448,300,940	39.94	307,921,834	41.52
	Barley	297,701	50.22	674,274,636	60.06	433,678,166	58.48
	Total	483,196	81.51	1,122,575,576	100	741,600,000	100
80	Clover	35,269	5.95	174,954,394	11.96	143,662,493	14.53
	Wheat	162,331	27.39	392,338,462	26.83	269,469,938	27.25
	Barley	395,171	66.66	895,028,470	61.21	575,667,569	58.22
	Total	592,771	100	1,462,321,326	100	988,800,000	100
100	Clover	133,729	22.56	660,580,098	38.47	544,723,395	44.07
	Wheat	111,021	18.73	268,321,863	15.63	184,294,996	14.91
	Barley	348,021	58.71	788,229,023	45.90	506,981,609	41.02
	Total	592,771	100	1,717,130,984	100	1,236,000,000	100
120	Clover	225,677	38.07	1,099,772,578	56.31	919,256,609	61.98
	Wheat	143,554	24.22	346,933,487	17.76	238,299,433	16.07
	Barley	223,540	37.71	506,288,627	25.92	325,643,958	21.96
	Total	592,771	100	1,952,994,693	100	1,483,200,000	100

Sensitivity analyses

To test the effectiveness of the mathematical model once an optimum cropping pattern is obtained, a sensitivity analyses were conducted. The analyses tested the variation in net return as the result of changing of irrigation water salinity from 0.5 to 2.5%, irrigation system efficiency from 40 to 70% and the availability of water from 80 to 115%. The results are summarized in Figures (1), (2) and (3).

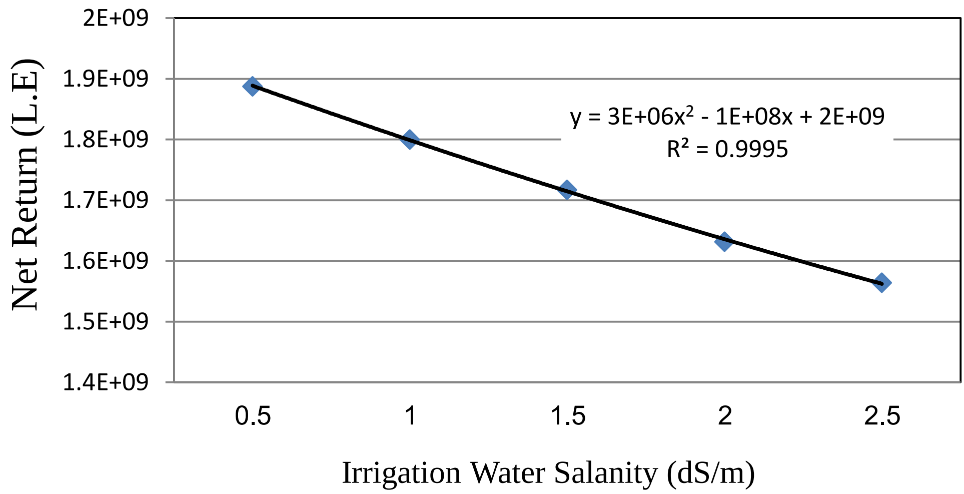

Fig. (1): Relationship between in income and irrigation water salinity

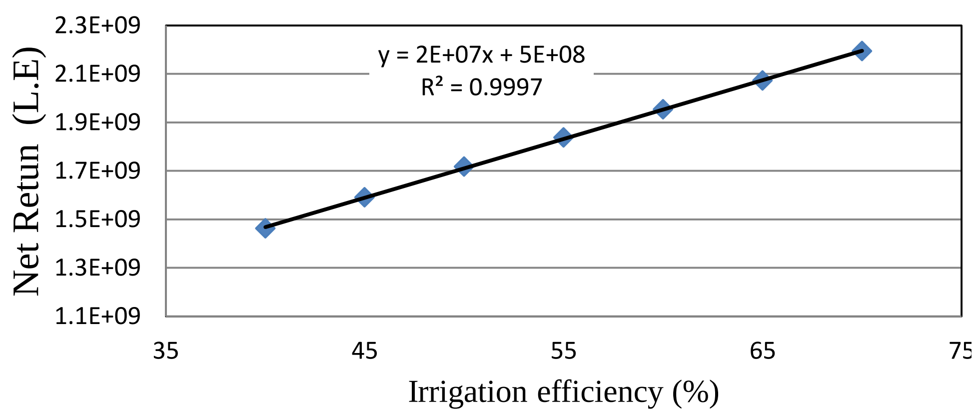

Fig. (2): Relationship between in income and irrigation efficiency

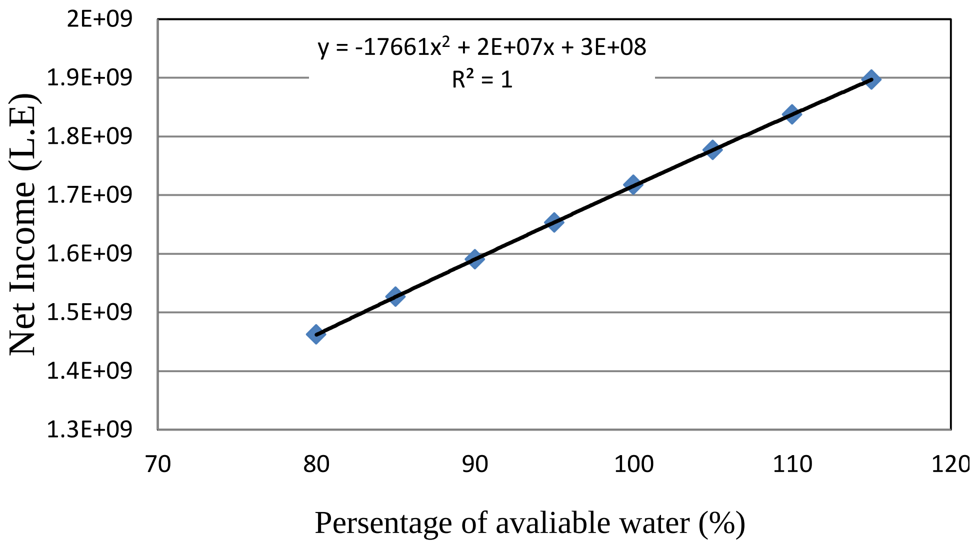

Fig. (3): Relationship between in income and available water

The second scenario

To fulfill the local market requirements a group of constraints were developed based on the governorate previous year crop pattern as given in Table (3). The first constraint was to cultivate wheat from 30 to 60 % of the total area as ($0.3\ A_t\ \leq\ A_{Wheat}\ \leq 0.6\ A_t$). The second constraint was to cultivate clover or barley ranged between 3 to 15% as ($0.03\ A_t\ \leq A_{Clover}\ or\ A_{Barley}\ \leq 0.15\ A_t$).

The rest of the crops cultivated area between 3 to 10% as ($0.03\ A_t\ \leq A_{Tomato}\ or\ A_{Flax}\ or\ A_{Bean}\ or\ A_{Sugar\ Bee\ t}\ \leq 0.1 A_t$). The results presented in Table. (8). Comparing the net income of the un-restricted and the restricted solution, one found the reduction by 4.4 % occurred due to taken in consideration the market requirements.

The third Scenario

A reasonable alternative in case of scarcity of water is to employ highly efficient irrigation methods. Therefore, it is proposed to irrigate the tomato crop by trickle irrigation system where the application efficiency is as high as 90 %, and sugar beet by sprinkler irrigation with 65% irrigation application efficiency. Due to the lake of official data about crop yield and cost of production for both tomato and sugar beet an assumptions were made based on literature data. The yield of tomato under the trickle irrigation systems increases by about 30% compared by surface furrow irrigation system. But, the irrigation cost (initial, running and maintenance) increases by about 400% (Jadhav et al. 1990). By calculating the total cost of tomato under trickle irrigation system showed increase as high as 4632 L.E./fed. The same way, the yield of sugar beet increases by about 20 % under hand move sprinkler system. Compared with border surface irrigation system the irrigation cost increases by 300% (Kaymag and Vanli, 1975). Therefore, the total cost of sugar beet was 3362 L.E./fed. After adjusting the yield and the total cost, and applying the un-restricted solution 2 (URS2). The model showed that the final income was 2,971,398,501 L.E. due to cultivating 85 % of the total land by tomato and the other 15 % by clover crop. The results presented in Table(9). By this solution 5.5% of the available water was saved.

The fourth scenario

The last scenario considered the restricted solution (RS2) with the same limits of cultivated area in (RS1). Considering the modern irrigation systems, tickle for tomato and sprinkler for sugar beet with the restricted solution results the total net income was 1,841,584,834 L.E as shown in Table. (10). Comparing this result with RS1, one found that the income increased by 12.18 % ,while decreased by 38 % relative to the un-restricted solution 2. The cultivated area by wheat, clover and tomato were 56, 15 and 10 % while the rest cultivated area of 3 % was cultivated by bean, barley, flax and sugar beet. By this solution 3.5% of the available water was saved.

Table (8): Results of Restricted Solution (RS1) for crop pattern and their share in area, net income and water consumption

Crop	Soil texture	Area		Net income		Water consumption	
		Feddan	%	L.E	%	m^3	%
Clover	(C)	71,374	12.04	354,055,499	21.57	290,730,027	23.52
	(S.C.L)	17,542	2.96	83,788,682	5.10	71,453,054	5.78
Total		88,916	15.00	437,844,181	26.67	362,183,081	29.30
Sugar Beet	(S.C)	80	0.01	191,338	0.01	183,752	0.01
	(C.L)	80	0.01	191,099	0.01	183,523	0.01
	(S.C.L)	17,264	2.91	41,402,996	2.52	39,761,602	3.22
	(L.F.S)	359	0.06	861,710	0.05	827,894	0.07
Total		17,783	3.00	42,647,143	2.60	40,956,771	3.31
Wheat	(S.C)	111,873	18.87	270,397,554	16.47	185,709,532	15.03
	(C.L)	59,197	9.99	143,080,033	8.72	98,267,627	7.95
	(S.C.L)	97,759	16.49	236,284,119	14.39	162,280,363	13.13
	(L.F.S)	69,050	11.65	166,823,924	10.16	114,622,398	9.27
Total		337,879	57.00	816,585,629	49.74	560,879,920	45.38
Barley	(S.C)	6,601	1.11	14,952,387	0.91	9,616,349	0.78
	(C.L)	0	0.00	113	0.00	73	0.00
	(S.C.L)	57,122	9.64	129,386,141	7.88	83,212,280	6.73
	(L.F.S)	19,507	3.29	44,164,774	2.69	28,416,295	2.30
Total		83,229	14.04	188,503,416	11.48	121,244,996	9.81
Bean	(S.C.L)	17,783	3.00	23,651,031	1.44	31,209,393	2.53
Total		17,783	3.00	23,651,031	1.44	31,209,393	2.53
Tomato	(C)	29,397	4.96	106,570,683	6.49	95,308,449	7.71
Total		29,397	4.96	106,570,683	6.49	95,308,449	7.71
Flax	(C)	17,783	3.00	25,866,043	1.58	24,217,390	1.96
Total		17,783	3.00	25,866,043	1.58	24,217,390	1.96
Summation		592,771	100	1,641,668,126	100	1,236,000,000	100

Table (9): Results of Un-Restricted Solution 2 (URS2) of the crop pattern and their shares in area, net income and water use (with applying trickle irrigation for Tomatoes and sprinkler irrigation for Sugar Beet)

Crop	Soil texture	Area		Net income		Water consumption	
		Feddan	%	L.E	%	m^3	%
clover	(L.F.S)	88,916	15	358,207,010	12.06	362,183,081	29.30
Total		88,916	15	358,207,010	12.06	362,183,081	29.30
Tomato	(C)	118,554	20	659,485,303	22.19	189,841,693	15.36
	(S.C)	118,554	20	595,371,010	20.04	189,841,693	15.36
	(C.L)	59,277	10	269,862,321	9.08	94,920,846	7.68
	(S.C.L)	207,470	35	1,088,472,857	36.63	332,222,962	26.88
Total		503,855	85	2,613,191,490	87.94	806,827,194	65.28
Summation		592,771	100	2,971,398,501	100	1,169,010,275	94.58

Table (10): Results of distributing water on crops and their share in area, net income.

Crop	Soil texture	Area		Net income		Water consumption	
		Feddan	%	L.E	%	m^3	%
Clover	(C)	41,494	7	205,833,660	11.18	169,018,771	13.67
	(S.C.L)	47,422	8	226,512,120	12.30	193,164,310	15.63
Total		88,916	15	432,345,780	23.48	362,183,081	29.30
Sugar Beet	(L.F.S)	59,277	10	187,400,995	10.18	103,658,929	8.39
Total		59,277	10	187,400,995	10.18	103,658,929	8.39
Wheat	(S.C)	118,554	20	286,545,501	15.56	196,799,972	15.92
	(C.L)	59,277	10	143,272,751	7.78	98,399,986	7.96
	(S.C.L)	124,482	21	300,872,776	16.34	206,639,971	16.72
	(L.F.S)	29,639	5	71,606,737	3.89	49,199,993	3.98
Total		331,952	56	802,297,765	43.57	551,039,922	44.58
Barley	(S.C.L)	17,783	3	40,280,568	2.19	25,905,695	2.10
Total		17,783	3	40,280,568	2.19	25,905,695	2.10
Bean	(S.C.L)	17,783	3	23,651,031	1.28	31,209,393	2.53
Total		17,783	3	23,651,031	1.28	31,209,393	2.53
Tomato	(C)	59,277	10	329,742,651	17.91	94,920,846	7.68
Total		59,277	10	329,742,651	17.91	94,920,846	7.68
Flax	(C)	17,783	3	25,866,043	1.40	24,217,390	1.96
Total		17,783	3	25,866,043	1.40	24,217,390	1.96
Summation		592,771	100	1,841,584,834	100	1,193,135,255	96.53

CONCLUSIONS

This research focuses on the vertical expansion of the agricultural sector through attempting to determine the optimum cropping mix that gives the maximum profit in the largest Egyptian agricultural governorate (EL-Behira). Therefore, a nonlinear optimization model was developed for this purpose. The model was run by Excel Microsoft Solver application. The Solver precision, tolerance and convergence were 0.000001, 5% and 0.0001 respectively. The model maximizes the profit based on crop salinity production function, constrains, prices, total cost, available area, available water and market considerations. The model selected the most profitable crop based on the crop water consumption, tolerance to soil salinity and net return. Four scenarios were conducted by the model to get the maximum net income. The first two considered the irrigation systems were surface for all cultivated crops. One of these based on un-restricted solution (URS1), means that the final profit based on the maximum income of the crop, regardless of the market requirements. By this scenario the final income was 1,717,136,466 L.E. The cultivated area was limited to fulfill the local market requirements, wheat cultivated area limited between 30 to 60%, clover and barley between 5 to 15% and the other crops between 3 to 5% only. This solution resulted in final income as 1,641,668,126 L.E. by 4.5% reduction in final income.

The second two scenarios considered tomato crop irrigated by trickle irrigation where the irrigation efficiency as high as 90% and sugar beet crop irrigated by sprinkler irrigation system with 65% irrigation application efficiency, meanwhile, the other crop still irrigated by surface irrigation systems with 50% irrigation application efficiency. The second un-restricted solution (URS2) of this scenario resulted in 2,971,398,501 L.E. due to cultivating 85 % of the total land by tomato and the other 15 % by clover crop. The final scenario considered the restricted solution (RS2) with the same limits of cultivated area in (RS1). The results indicated that final income was 1,841,584,834 L.E., which higher than (URS1) by 12%, less than (URS2) BY 73% and higher than (RS1) by 38%. Shares of area, income and water of the crops under Restricted and Un-Restricted Solutions for all surface irrigation systems or surface and modern system are presented in Table(11).

Table (11): Brief results of the model output for the four scenarios.

Crop	All the crops applied surface irrigation system (50% application efficiency)						Tomatoes applied trickle, Sugar Beet applied sprinkler, others applied surface system					
	Un-Restricted Solution (URS1)			Restricted Solution (RS1)			Un-Restricted Solution (URS2)			Restricted Solution (RS2)		
	Area	Income	Water	Area	Income	Water	Area	Income	Water	Area	Income	Water
Clover	22.56	38.47	44.07	15.00	26.67	29.50	15.00	12.06	29.30	15.00	23.48	29.30
Sugar Beet	18.71	15.61	14.89	3.00	2.60	3.31	85.00	87.94	65.28	10.00	10.18	8.39
Wheat	58.73	45.95	41.04	57.00	49.74	45.48	-	-	-	56.00	43.57	44.59
Barley	-	-	-	14.04	11.48	9.81	-	-	-	3.00	2.19	2.10
Bean	-	-	-	3.00	1.44	2.53	-	-	-	3.00	1.28	2.53
Tomato	-	-	-	4.96	6.49	7.71	-	-	-	10.00	17.91	7.68
Flax	-	-	-	3.00	1.58	1.69	-	-	-	3.00	1.4	1.56
Total	100	100	100	100	100	100	100	100	94.58	100	100	96.53

REFERENCES

Ali, N. A. (2003). An Economic Study for the Crop Pattern in New Lands In Light of the Liberalization of Input and Output Markets.(Unpublished doctoral dissertation), Cairo University, Cairo

Allen, R.G.; Jensen, M.E.; Wright, J.L. and Burman, R.D. (1989). Operational estimate of reference evapotranspiration. Agronomy Journal, No. 81, 650-662

Aly, A.; S. Ahmed and E. Saleh, (2007). Suitable Cropping Patterns for the Egyptian Desert Lands in the Context of Groundwater Limitation. Egyptian Journal of Agricultural Economics, 17(3), 933 – 947.

Ayers, R.S., and D.W. Westcot,. 1985. Water Quality for Agriculture, FAO Irrigation and

Chaves Morales, J., Marino, M. A. and Holzapfel, E. A. (1992). Planning Simulation Model of Irrigation District . J. irrig and Drain . eng., ASCE, 118(1), 74 – 87.

Drainage Paper 29 rev 1. FAO, UN, Rome 174pp. Chavez-Morales, J., Marino, M. A., and Holzapfel, E. A. (1992). Planning simulation model of irrigation district. J. Irrig. and Drain. Engrg., ASCE. 118(1), 74-87.

El-Kheshen, M. (1992). An Economic Study for the Egyptian Crop Pattern In light of the Current Global Economic Changes. (Unpublished doctoral dissertation), Al Azhar University, Cairo.

Environmental Description of EL-Behaira governorate (2008). http://www.eeaa.gov.eg/English/reports/GovProfiles/final/Behaira%20Des.pdf

Enaber, M. A., Sakr, A. M., and Hussein, Z. M. (2009). The Optimum Crop Pattern Under the Available Economic Resources. Journal of Agricultural Science Mansoura University, 34(9), 9289 - 9302.

Food and Agricultural Organization of the United Nations (FAO). (2011). Aquastat, 2011 [Data file]. Retrieved June 28, 2011 from FAO. http://www.fao.org/nr/water/aquastat/main/index.stm

Hanna, M. Z. (1970). An Economic Study for the Optimal Crop Pattern in Dakahlya Governorate. (Unpublished Masters dissertation), Ain Shams University, Cairo.

Hassan, I.; Raza, M.; Khan, I.; and Ilahi, R. (2005). Use of Linear Programming Model to Determine the Optimum Cropping Pattern, Production and Income Level: A Case Study from Dera Ghazi Khan Division. Journal of Agriculture and Social Sciences, 1(1), 32-34.

Henderson, J. (1959). The Utilization of Agricultural Land: A Theoretical and Empirical Inquiry. The Review of Economics and Statisitics, 41(3), 242-259.

Hillier, F., and Lieberman. G. (1980). Introduction to operation research. Holden –Day, Inc., San Francisco, Calif.

Hussein, Z., & Eita, M. (2001). The Adaptable Crop Pattern in the Light of the Available Water Requirements in Southern Valley. Egyptian Journal of Agricultural Economics, 37-52.

Ismail, S.; and Ata, S. (2005). An Analytical Study of Optimum Crop Pattern in Egypt. Egyptian Journal of Agricultural Economics, 15(4), 1175-1192.

Jadav-ss, Gutal-GB and Chougle-AA, (1990). Cost of economics of drip irrigation system for Tomato crop. Proc. Of the 11th Int. Con. On the use of Plastics in Ag. New Dalhi. 101 : 111.

Kaymag, S., and N. Vanli, (1975). Determination of Sugar Beet yield quantity and economic utility of different irrigation methods. Seker, 26 (100): 10:29 (Turkey)

Ministry of Agriculture and Land Reclamation, Economic Affairs Sector. Statistics of Prices, Costs, and Net Returns of Winter crops 2009-2010. http://www.agr-egypt.gov.eg/Uploads/Studies/378c7230-2e70-4df2-bdbf-01993ac26e46.pdf

Mohamad, M. A. (1992). Alternative Crop Patterns in the Egyptian Agriculture. (Unpublished Masters dissertation), Cairo University, Cairo.

Mohamad, N., & Said, F. (2011). A Mathematical Programming Approach to Crop Mix Problem. African Journal of Agricultural Research, 6(1), 191-197.

National Water Research Center, Drainage Research Institute, 1997. Final report on Drainage Water Irrigation Project (DWIP). Cairo, Egypt.

Piech, B., &Rehman, T. (1993). Application of Multiple Criteria Decision Making Methods to Farm Planning: A Case Study. Agricultural Systems, 41, 305 – 319.

Sarker, R., Talukdar, S., & Haque, A. F. (1997). Determination of Optimum Crop Mix for Crop Cultivation in Bangladesh. Application Mathematical Modelling, 21, 621-632.

Siam, G. (1973). Crop Production Planning in Egypt Using Linear Programming. (Unpublished doctoral dissertation), Cairo University, Cairo.

Singh, D.K., Jaiswal, C.S., Reddy, K.S., Singh, R,M, &Bhandarkar, D.M. (2001). Optimal Cropping Pattern in a Canal Command Area. Agricultural Water Management, 50, 1-8.

Siskos, Y., Despotis, D. & Ghediri, M. (1994). Multiobjective Modelling for Regional Agricultural Planning: Case Study in Tunisia. European Journal of Operational Research, 77, 375-391.

الملخص العربي

التركيب المحصولى الامثل لمحافظة البحيرة (الموسم الشتوى)

أ.د جمال شرف[١] د.عزة عبد الفتاح[٢] دهيثم حسين[٣]

يهدف البحث إلى تعظيم العائد من زراعة المحاصيل الشتوية لمحافظة البحيرة. حيث تم اختيار سبعة محاصيل سائد زراعتها في الموسم الشتوي لمحافظة البحيرة وتمثل ٩٧,٥% من المساحة المحصولية. وهذه المحاصيل هي البرسيم المستديم والقمح والشعير و الفول البلدي وبنجر السكر والطماطم والكتان. ولتحقيق هذا الهدف تم بناء نموذج رياضي مكون من دالة الهدف وهى لتعظيم العائد الناتج من زراعة هذه المحاصيل كدالة لمساحات غير محددة وتقوم بخصم التكاليف الكلية من قيمة المحصول السوقية بعد الحصاد.

١ - أستاذ الهندسة الزراعية - كلية الزراعة، سابا باشا – جامعة الإسكندرية - ج.م.ع.
٢ - باحث أول - معهد بحوث الهندسة الزراعية - وزارة الزراعة - ج.م.ع.
٣- مدرس الهندسة الزراعية - كلية الزراعة، سابا باشا – جامعة الإسكندرية - ج.م.ع.

هذا بالإضافة إلى مجموعة من القيود المحددة للمساحات المزروعة من كل محصول وكميات المياه المخصصة له في الموسم المستوى من حصة المحافظة. وقد تم ربط الإنتاجية للمحاصيل المختلفة بتأثر التربة بالملوحة وتم الأخذ في الاعتبار كفاءة نظم الري المستخدمة وملوحة ماء الري والاحتياجات الغسيليه لحفظ التوازن الملحي للتربة لوقف عجز الإنتاج. وقد تم الحصول على الأسعار والإنتاجية والمخصصات المائية لعام ٢٠١٠ لمحافظة البحيرة من واقع البيانات الرسمية لوزارة الزراعة واستصلاح الأراضي. وأظهرت نتائج النموذج، انه في حالة الرغبة في الحصول على أقصى عائد يشكل مطلق بصرف النظر عدد المحاصيل التي يمكن زراعتها واحتياجات السوق، فأظهرت النتائج أن زراعة ثلاثة محاصيل وهى البرسيم المستديم والشعير والقمح كافيه لتحقيق دالة الهدف للحصول على أقصى عائد وهو ١٧١٧١٣٦٤٦٦ جنيه مصري. ومحصول الشعير يقع في المرتبة الأولى ويزرع على ٥٨,٧ % من مساحة الأرض ويستهلك ٤١ % من المخصصات المائية ويساهم بمقدار ٤٥,٩ % من العائد. وفى المرتبة الثانية محصول البرسيم المستديم ويزرع على مساحة ٢٢,٦ % ويستهلك ٤٤,٧ % من المخصصات المائية ويساهم بمقدار ٣٨,٥ % من العائد. أما في المرتبة الثالثة يأتي القمح ليزرع على ١٨,٧% من مساحة الأرض ويستهلك ١٤,٩ % من المخصصات المائية ويساهم بمقدار ١٥,٦١ % من العائد. ويعزى اختيار الشعير والقمح إلى تحملهم ملوحة التربة والاستهلاك الأقل من مياه الري والغسيل بعكس محصول البرسيم والذي له عائد مادي عالي لكن تتأثر الإنتاجية بارتفاع ملوحة التربة واستهلاكه العالي من مياه الري. وقد سمى الحل السابق بالحل الغير مقيد (URS1) لاعتماده على تعظيم العائد بصرف النظر عن أي اعتبارات أخرى.

ولكن هناك اعتبارات لاستهلاك السوق المحلى أو اعتبارات الأمن الغذائي والتي يجب أن تؤخذ في الاعتبار. وبناء على ذلك تم اخذ مؤشرات من إنتاج الأعوام السابقة لمحافظة البحيرة لفصل الشتاء. وتم تقيد مساحات محاصيل الطماطم والفول والكتان وبنجر السكر في حدود من ٣% – ١٠% ، ومن ٥ % - ١٥% لمحاصيل البرسيم والشعير، ومن ٣٠ %– ٦٠% لمحصول القمح. وأظهرت نتائج هذا الحل والذي سمى بالحل المقيد (RS1)، أن مقدار صافى الدخل مقداره 1641668126 جنيه مصري بعجز مقداره ٤,٥ % من الحل الغير مقيد (URS1) . واحتل محصول القمح المرتبة الأولى من حيث شغل المساحة المحصولية للمحافظة في الموسم الشتوي بنسبة ٥٧ % ثم البرسيم بنسبة ١٥ % ثم الشعير بنسبة ١٤,٠٤ % ثم الطماطم بنسبة ٤,٩٦ % ثم كل من بنجر السكر والفول البلدي والكتان بنسبة ٣ %. ومع محدودية كميات مياه الري يجب استخدام النظم الحديثة لتوفير كميات من مياه الري ورفع الإنتاجية وزيادة العائد. فتم اقتراح زراعة محصول الطماطم بالري بالتنقيط ويمتاز هذا الخيار بتوفير المياه لارتفاع كفاءة الري بالتنقيط إلى ٩٠ % مع زيادة الإنتاجية بمقدار الثلث. وكذلك ري محصول بنجر السكر بالري بالرش مع كفاءة ري ٦٥ % وزيادة الإنتاجية بمقدار ٢٠%. وقد تم تعديل التكاليف الكلية لهذه المحاصيل لارتفاع تكاليف الري بهذه النظم مقارنه بالري السطحي. ومع تطبيق الحل الغير

مقيد (URS2)، أظهرت النتائج أن النموذج الرياضي اختار محصولي الطماطم والبرسيم المستديم فقط لتحقيق دالة الهدف والوصول بالعائد إلى 2971398501 جنيه مصري. واحتل محصول الطماطم ٨٥ % من المساحة الكلية بينما محصول البرسيم على ١٥ %. وبمقارنة هذا الحل بالحل الغير مقيد السابق (URS1) نجد أن العائد زاد بنسبة ٧٣% هذا بالإضافة إلى توفير ٥,٥ % من كميات المياه المتاحة. كما تم تطبيق الحل المقيد (RS2) مع استخدام الري بالتنقيط لمحصول الطماطم والري بالرش لمحصول بنجر السكر. فأظهرت النتائج وصول العائد إلى 1841584834. وبذلك يزداد الدخل بمقدار ١٢,١٨ % عن الحل المقيد السابق (RS1) والذى يجرى فيه الرى لكافة المحاصيل بالرى السطحى. ويقل هذا الدخل بمقدار ٣٨,٠٢ % من الحل الغير مقيد مع تطبيق الرى بالتنقيط للطماطم والرى بالرش لبنجر السكر (URS2) . ويحتل محصول القمح المرتبة الأولى للمساحة الكلية بنسبة ٥٦ % يليه محصول البرسيم بنسبة ١٥ % ثم الطماطم بنسبة ١٠ % ثم الفول والشعير والكتان وبنجر السكر بنسبة ٣ %. هذا بالإضافة إلى توقير ٣,٥ % من مياه الري المخصصة لمحافظة البحيرة. هذا وقد أجريت بعض اختبارات لبيان مدي دقة النموذج الرياضي وذلك بدراسة التغير في العائد نتيجة التغير في كميات مياه الري المتاحة وملوحة مياه الري وكفاءة نظام الري المستخدم. وأظهرت النتائج زيادة العائد مع ارتفاع كفاءة نظام الري وازدياد كميات مياه الري المتاحة وانخفاض العائد مع زيادة ملوحة ماء الري.