AN ECONOMIC STUDY ON WATER ALLOCATION TO ACHIEVE FOOD SECURITY IN EGYPT

Mohammed Youssuf Sultan [1], Hammad Hosni Ahmed El Sayed [1] and Enas Moh. Abbas Saleh [2]

[1] Prof. Dr., Chief Researcher, [2] Dr., Researcher,
Agricultural Economics Research Institute, Agricultural Research Center, Egypt

ABSTRACT

The economic exploitation of agricultural resources is one of the main goals of agricultural policy to achieve sustainable agricultural development. On the other hand, the method of linear programming is one of the most important mathematical techniques designed to distribute economic resources among alternative uses so as to achieve the optimal use. Accordingly, this study aims at characterizing the cropping patterns that maximizes the net return per feddan, minimizes water requirements and maximizes the net return per water unit for the cropping pattern of the year 2006. To accomplish the study main goals, three linear programming models were applied as a tool for economic planning.

The main objectives of these scenarios are maximizing the total net revenues for the cropping pattern calculated, maximizing the total net revenues for the cropping pattern, minimizing water irrigation requirements, and maximizing the total net revenues for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops.

The results of solving the linear programming models for the cropping pattern found out that the optimum combination of crops can be produced according to the third scenario, since it achieves an increase in the total net revenue for the cropping pattern of about 0.13%. Moreover, it saves about 4.28% of the water irrigation, as well as achieving greater return per unit of water resources of about 4,61% as compared to those achieved by the cropping pattern of the year 2006 in addition to achieving suitable self-sufficiency ratios of most major crops.

INTRODUCTION

The Egyptian economy has traditionally relied heavily on agriculture as a source of growth and support for the non-agricultural sectors of the economy. This pivotal role of the agricultural sector was reinforced by the strong performance of the sector since it accounts for a significant share of growth, exports and employment.

However, the current policy of the Government of Egypt (GoE) concerning crop development is essentially dictated by the need for rationalizing the use of scarce water resources, in order to maximize production per unit of water while maintaining acceptable levels of food security for the years to come. On the other hand, farmers tend to allocate more land for producing cash crops.

Moreover, the cropping pattern expresses the percentage of land occupied by the various crops in crop rotation. This is determined by specifying the area cultivated by each crop and the system of crop succession. Thus, the cropping pattern is considered as a mechanism for the use of agricultural economic resources since it reflects the features of land allocation for producing different crops. Accordingly, the current study examines the optimum use of agricultural land resources in Egypt.

Based on the current study, the problem is present in an attempt to answer a series of questions, namely:

- Which crops should be included into the cropping pattern to maximize the farmer's profits?
- Which crops should be included into the cropping pattern to minimize water irrigation and save water resources?
- Which crops should be included into the cropping pattern to maximize the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops?

Accordingly, the objectives of this study are mainly concerned with characterizing the cropping patterns that maximizes the total net revenues for the cropping pattern calculated, maximizes the total net revenues for the cropping pattern, minimizes water irrigation requirements, and maximizing the total net revenues for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops.

To fulfill the study main goals, linear and goal programming models were applied as one of the most important mathematical techniques designed to distribute economic resources among alternative uses so as to achieve the optimal use considering some constraints. This study depends on secondary data collected from different sources.

MODEL DESCRIPTION

The current study aims at solving linear and goal programming models for the cropping pattern, through the formulation of four scenarios for the cropping pattern based on Egypt's cropping pattern in 2006. The main objectives of these scenarios are as following:

- Maximizing the total net revenue for the cropping pattern.
- Minimizing water irrigation requirements for the cropping pattern.
- Maximizing the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops.

The main objective functions of these scenarios are as following:

A- In case of maximizing the total net revenue for the cropping pattern:

$$\text{Max}: \Pi = \pi_1 X_1 + \cdots + \pi_{40} X_{40}$$

Subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \le R_i \quad (i = 1,2,\ldots,m)$$

$$X_j \ge 0 \quad (j = 1,2,\ldots,n)$$

Where,

Π : The total net revenue for the cropping pattern from all agricultural activities "crops" (j), which include 40 crops.

π_j : The net revenue for each agricultural activity "crop" (j), where (j = 1, 2,..., 40).

X_j : The area cultivated by each agricultural activity "crop" (j), where (j = 1, 2,..., 40).

a_i : The size of per feddan constraint for each agricultural activity "crop" (j), where (i=1, 2,..., 12).

R_i : The per feddan constraints for agricultural production, where (i=1, 2,..., 12).

B- In case of minimizing water requirements for the cropping pattern:

$$\text{Min}: W = w_1 X_1 + \cdots + w_{40} X_{40}$$

Subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \le R_i \quad (i = 1,2,\ldots,m)$$

$$X_j \ge 0 \quad (j = 1,2,\ldots,n)$$

Where,

W : The total water requirements for the cropping pattern of all agricultural activities "crops" (j), which include 40 crops.

w_j : The monthly per feddan water requirements for each agricultural activity "crop" (j), where (j = 1, 2,..., 40).

X_j : The area cultivated by each agricultural activity "crop" (j), where (j = 1, 2,..., 40).

a_i : The size of per feddan constraint for each agricultural activity "crop" (j), where (i=1, 2,..., 12).

R_i : The per feddan constraints for agricultural production, where (i=1, 2,..., 12).

The alternative agricultural activities are as following:

These agricultural activities include 40 crops cultivated in winter, summer and Nili seasons as following:

A- The agricultural activities for winter season include 19 crops; wheat, barley, fenugreek, broad bean, lentils, lupine, chickpeas, flax, sugar beets, short-season

clover, long-season clover, onions, garlic, tomatoes, potatoes, squash, peas, cabbage and pepper.

B- The agricultural activities for summer season include 16 crops; rice, maize, sorghum, soya beans, sesame, peanut, sunflower, sugar cane, cotton, tomatoes, potatoes, cucumber, squash, eggplant, pepper and melon.

C- The agricultural activities for Nili season include 5 crops; maize, green beans, tomatoes, potatoes and cabbage.

The constraints of these models are as following:

These constraints can be classified into three major groups; natural constraints, the constraints of production costs and regulatory constraints:

A- The natural constraints include 3 constraints; cultivated area, water irrigation and agricultural labor:

1- The cultivated area: Three constraints of them are concerned with the cultivated area by the studied crops for winter, summer and Nili seasons. On the other hand, the fourth constraint is concerned with the cropped area of the studied crops. According to these constraints, the cultivated areas must not exceed their similar areas for the year 2006, thus reaching about 12.29, 6.36, 5.51 and 0.41 million feddans, respectively as illustrated in Table (1). However, the cultivated areas of horticulture and palms are excluded.

Table (1): The natural constraints concerned with the cultivated area: (Thousand feddans)

Item	Constraint	Maximum limit
Cultivated area by the studied crops for winter season	≤	6363.0
Cultivated area by the studied crops for summer season	≤	5509.5
Cultivated area by the studied crops for Nili season	≤	413.5
Cropped area of the studied crops	≤	12286.0

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007.

2- The water irrigation: These are twelve constraints reflecting available water irrigation per month for the studied crops. According to these constraints, the total volume of water irrigation per month must not exceed the total volume of water irrigation per month for the year 2006, reaching about 33,008 million cubic meters (MCM) as illustrated in Table (2).

Table (2): The natural constraints concerned with the water irrigation: (million cubic meters (MCM))

Months	Constraint	Maximum limit
January	≤	1536.1
February	≤	1881.0
March	≤	2564.5
April	≤	2779.9
May	≤	2359.3
June	≤	4656.1
July	≤	5659.1
August	≤	5611.1
September	≤	2310.2
October	≤	934.8
November	≤	1094.3
December	≤	1621.2
Total	≤	33007.6

Source: compiled and calculated from the Central Authority for Public Mobilization and Statistics (CAPMAS), Records of Water Resources and Irrigation, July 2007.

3- Agricultural labor: These are twelve constraints reflecting available agricultural labor per month for the studied crops. According to these constraints, the total agricultural labor per month must not exceed the total agricultural labor per month for the year 2006, reaching about 855 million man/days of work as illustrated in Table (3).

Table (3): The natural constraints concerned with agricultural labor: (million man/days of work)

Months	Constraint	Maximum limit
January	≤	57.6
February	≤	31.5
March	≤	48.1
April	≤	48.7
May	≤	121.4
June	≤	88.7
July	≤	102.5
August	≤	73.4
September	≤	68.3
October	≤	117.1
November	≤	55.2
December	≤	42.5
Total	≤	855.0

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007.

B- The constraints of production costs including the total cost of inputs, agricultural labor, animal work, machinery, seeds, manure, fertilizers, pesticides and other expenses. This constraint requires no more costs of production for the studied crops than the total costs of production for these crops in the year 2006, estimated at L.E. 17.51 billion as illustrated in Table (4).

Table (4): The constraints concerned with the costs of production: (L.E. million)

Cost item	Constraint	Maximum limit
Agricultural Labor	≤	5640.0
Animal Work	≤	91.0
Machinery	≤	3547.7
Seeds	≤	2383.1
Manure	≤	802.9
Fertilizers	≤	2701.5
Pesticides	≤	783.7
Other Expenses	≤	1555.5
Total Costs	≤	17505.8

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007.

C- The regulatory constraints include:

- A constraint considering the rationalization of water irrigation: this constraint requires no more rice cultivated area than the maximum area cultivated by rice during the period (2003-2006).
- Some constraints to ensure increased production of cereals, pulses, oil crops and sugar crops: these constraints require no less cultivated area by major strategic crops i.e. wheat, maize, rice, broad bean, lentils, soya beans, sesame, peanut, sunflower, sugar cane and sugar beets than the minimum area cultivated by these crops during the respective period (2003-2006) in order to increase these crop production and bridge the gap between their production and consumption and attaining food security.
- A marketing constraint on vegetables: this constraint requires no more cultivated areas by vegetables than the maximum area cultivated by these crops during the period (2003-2006) since the production of vegetables exceeds the domestic consumption and export requirements of vegetables, resulting in some difficulties to predict the potential market for vegetables.
- A constraint considering the provision industrial raw materials: this constraint requires no less cultivated area by cotton and flax, sugar cane and sugar beet than the minimum area cultivated by these crops during the respective period (2003-2006) in order to provide factories with the minimum needs of raw materials.

- A general constraint on the cultivated areas of other crops requires no less cultivated area by these crops than the minimum area cultivated by them during the period (2003-2006) and no more cultivated area by these crops than the maximum area cultivated by them during the respective period in order to ensure the exclusion of any crop.

The results of solving linear programming models for the cropping patterns:

The results of the first scenario: Maximizing the total net revenue for the cropping pattern:

Table (5) illustrates the cropping pattern according to the first scenario compared to the cropping pattern of 2006, indicating that changes in the winter crops produced according to this scenario refer to an increase in the area cultivated by some crops i.e. barley, lentils, flax, short-season clover, onions, garlic, tomatoes, squash, peas and cabbage, besides a decrease in the area cultivated by other crops i.e. fenugreek, broad bean, lupine, chickpeas, sugar beets, long-season clover, potatoes and pepper. On the other hand, the area cultivated by wheat did not change. However, the total net revenue for the area cultivated in winter season reached about L.E. 15.79 billion in 2006 compared to about L.E. 15.89 billion for the suggested cropping pattern according to this scenario, indicating an increase of about L.E. 106.00 million for the suggested cropping pattern according to this scenario.

Table (5): The cropping pattern according to the first scenario compared to 2006

Crops	Cropping Pattern of 2006			Cropping Pattern Proposed According to the First Scenario			Changes in Cultivated Area	Changes in the Net Revenue for the Total Cultivated Area
	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Net Revenue for the Total Cultivated Area (L.E. millions)	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Net Revenue for the Total Cultivated Area (L.E. millions)	(Thousand Feddans)	(L.E. Millions)
Wheat	3064.00	24.94	5709.00	3064.00	24.94	5709.00	0.00	0.00
Barley	214.50	1.75	110.00	215.00	1.75	110.00	0.50	0.26
Fenugreek	15.00	0.12	28.00	12.00	0.10	22.00	-3.00	-5.58
Broad bean	198.40	1.61	274.00	198.00	1.61	274.00	-0.40	-0.55
Lentils	1.50	0.01	1.00	2.00	0.02	1.00	0.50	0.36
Lupine	3.40	0.03	5.00	3.00	0.02	4.00	-0.40	-0.55
Chickpeas	15.20	0.12	15.00	13.00	0.11	13.00	-2.20	-2.23
Flax	15.60	0.13	24.00	16.00	0.13	25.00	0.40	0.61
Sugar beets	186.40	1.52	321.00	186.00	1.51	320.00	-0.40	-0.69
Short-season clover	470.20	3.83	817.00	533.80	4.34	928.00	63.60	110.54
Long-season clover	1657.00	13.49	6027.00	1652.50	13.45	6010.00	-4.50	-16.37

Onions	65.50	0.53	221.00	69.70	0.57	236.00	4.20	14.20
Garlic	17.30	0.14	117.00	23.00	0.19	155.00	5.70	38.41
Tomatoes	209.10	1.70	1677.00	215.00	1.75	1725.00	5.90	47.33
Squash	21.80	0.18	54.00	24.00	0.20	59.00	2.20	5.44
Peas	52.20	0.42	109.00	60.00	0.49	125.00	7.80	16.30
Cabbage	28.20	0.23	90.00	33.00	0.27	105.00	4.80	15.31
Potatoes	102.40	0.83	141.00	18.00	0.15	25.00	-84.40	-116.43
Pepper	25.30	0.21	48.00	25.00	0.20	48.00	-0.30	-0.57
Total area cultivated in Winter Season	6363.00	51.79	15788.00	6363.00	51.79	15894.00	0.00	106.00
Rice	1593.00	12.97	3232.00	1583.70	12.89	3213.00	-9.30	-18.87
Maize	1711.00	13.93	3219.00	1751.60	14.26	3295.00	40.60	76.38
Sorghum	367.50	2.99	443.00	351.00	2.86	423.00	-16.50	-19.88
Soya beans	17.80	0.14	12.00	18.00	0.15	13.00	0.20	0.14
Sesame	73.40	0.60	81.00	67.00	0.55	74.00	-6.40	-7.05
Peanut	132.10	1.08	320.00	132.00	1.07	320.00	-0.10	-0.24
Sunflower	35.70	0.29	23.00	32.00	0.26	21.00	-3.70	-2.39
Sugar cane	326.90	2.66	1393.00	321.00	2.61	1368.00	-5.90	-25.14
Cotton	536.40	4.37	1442.00	536.00	4.36	1441.00	-0.40	-1.08
Tomatoes	241.30	1.96	1067.00	241.00	1.96	1066.00	-0.30	-1.33
Potatoes	79.10	0.64	254.00	103.30	0.84	331.00	24.20	77.65
Cucumber	60.50	0.49	151.00	44.00	0.36	109.00	-16.50	-41.06
Squash	59.60	0.49	188.00	73.00	0.59	230.00	13.40	42.27
Eggplant	58.40	0.48	137.00	58.00	0.47	136.00	-0.40	-0.94
Pepper	59.60	0.49	61.00	39.00	0.32	40.00	-20.60	-21.13
Melon	157.20	1.28	604.00	159.00	1.29	611.00	1.80	6.92
Total area cultivated in Summer Season	5509.50	44.84	12627.00	5509.60	44.84	12691.00	0.00	64.00
Maize	282.50	2.30	375.00	283.00	2.30	375.00	0.50	0.66
Green beans	7.70	0.06	21.00	4.50	0.04	12.00	-3.20	-8.63
Tomatoes	74.00	0.60	818.00	77.00	0.63	851.00	3.00	33.15
Potatoes	39.00	0.32	57.00	39.00	0.32	57.00	0.00	0.00
Cabbage	10.30	0.08	35.00	10.00	0.08	34.00	-0.30	-1.03
Total area cultivated in Nili Season	413.50	3.37	1305.00	413.50	3.37	1329.00	0.00	24.00
The Grand Total	12286.00	100.00	29720.00	12286.10	100.00	29914.00	0.10	194.00

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the first scenario.

Moreover, the changes in summer crops according to this scenario showed an increase in the area cultivated by some crops i.e. potatoes, squash, maize, melon and soya beans. On the contrary, the rest of the areas cultivated by other summer crops decreased. However, the total net revenue for the area cultivated in summer season reached about L.E. 12.63 billion in 2006 compared to about L.E. 12.69 billion for the

suggested cropping pattern according to this scenario, indicating an increase estimated at about L.E. 64.00 million for the suggested cropping pattern according to this scenario.

Nevertheless, the changes in Nili crops according to this scenario showed an increase in the area cultivated by tomatoes and maize only. On the other hand, the area cultivated by green beans and cabbage decreased. Yet, the rest of the areas cultivated by potatoes didn't change. However, the total net revenue for the area cultivated in Nili season reached about L.E. 1.31 billion in 2006 compared to about L.E. 1.33 billion for the suggested cropping pattern according to this scenario, indicating an increase of about L.E. 24.00 million for the suggested cropping pattern according to this scenario.

However, Table (6) shows a summary of the results of solving linear programming models according to the first scenario, indicating an increase in the net revenue for the total cultivated area from L.E. 29.720 million in 2006 to reach about L.E. 29.914 billion for the cropping pattern according to the first scenario. This result shows that the cropping pattern according to the first scenario increases the net revenue for the total cultivated area by about 0.649% compared to the cropping pattern in 2006, which means that the proposed cropping pattern according to the first scenario achieves the goal of this model.

On the other hand, the total water irrigation requirements for the cropping pattern of 2006 reached about 33.008 BCM, compared to about 32.824 BCM for the cropping pattern according to the first scenario. This result shows that the cropping pattern according to the first scenario decreases the total water irrigation requirements by about 0.561% compared to the cropping pattern in 2006.

Table (6): A summary of the results obtained by solving the linear programming models according to the first scenario

Item	Cropping Pattern of 2006	Cropping Pattern Proposed According to First Scenario	% of Change
Total Cropped Area (million feddans)	12.286	12.286	0
Total Net Revenue for the Total Cropped Area (L.E. billion)	29.720	29.914	0.649
Total Water Requirements (BCM)	33.008	32.824	-0.561

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the first scenario.

The results of the second scenario: Minimizing water irrigation requirements for the cropping pattern:

Table (7) illustrates the cropping pattern according to the second scenario compared to the cropping pattern of 2006, indicating that changes in the winter crops produced

according to this scenario refer to an increase in the area cultivated by some crops i.e. wheat, barley, lentils, flax, short-season clover, long-season clover, onions, garlic, tomatoes, potatoes, squash, peas and cabbage. On the contrary, the rest of the areas cultivated by other winter crops decreased. However, the total water irrigation requirements for the area cultivated in winter season reached about 11.42 BCM in 2006 compared to about 11.29 BCM for the suggested cropping pattern according to this scenario, indicating a decrease estimated at about 136.00 MCM for the suggested cropping pattern according to this scenario.

Moreover, the changes in summer crops according to this scenario showed an increase in the area cultivated by some crops i.e. maize, soya beans, cotton, potatoes, squash, and melon. On the contrary, the rest of the areas cultivated by other summer crops decreased. However, the total water irrigation requirements for the area cultivated in winter season reached about 20.64 BCM in 2006 compared to 20.28 BCM for the suggested cropping pattern according to this scenario, indicating a decrease estimated at 359.00 MCM for the suggested cropping pattern according to this scenario.

Nevertheless, the changes in Nili crops according to this scenario showed an increase in the area cultivated by tomatoes and maize only. Moreover, the area cultivated by green beans and cabbage decreased. Yet, the rest of the areas cultivated by potatoes didn't change. However, the total water irrigation requirements for the area cultivated in winter season reached 950.30 MCM in 2006 compared to 949.94 MCM for the suggested cropping pattern according to this scenario, indicating a decrease of about 0.36 MCM for the suggested cropping pattern according to this scenario.

Table (7): The cropping pattern according to the second scenario compared to 2006

Crops	Cropping Pattern of 2006			Cropping Pattern Proposed According to Second Scenario			Changes in Cultivated Area	Changes in the Water irrigation Requirements for the Total Cultivated Area
	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Water irrigation Requirements for the Total Cultivated Area (MCM)	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Water irrigation Requirements for the Total Cultivated Area (MCM)	(Thousand Feddans)	(BCM)
Wheat	3064.00	24.94	4780.00	3088.90	25.14	4819.00	24.90	38.84
Barley	214.50	1.75	277.00	215.00	1.75	278.00	0.50	0.65
Fenugreek	15.00	0.12	20.00	12.00	0.10	16.00	-3.00	-3.98
Broad bean	198.40	1.61	237.00	198.00	1.61	237.00	-0.40	-0.48
Lentils	1.50	0.01	3.00	2.00	0.02	3.00	0.50	0.85
Lupine	3.40	0.03	5.00	3.00	0.02	4.00	-0.40	-0.55
Chickpeas	15.20	0.12	25.00	13.00	0.11	21.00	-2.20	-3.59
Flax	15.60	0.13	18.00	16.00	0.13	19.00	0.40	0.47
Sugar beets	186.40	1.52	346.00	131.00	1.07	243.00	-55.40	-102.93

Short-season clover	470.20	3.83	443.00	544.10	4.43	513.00	73.90	69.61
Long-season clover	1657.00	13.49	4174.00	1676.00	13.64	4222.00	19.00	47.86
Onions	65.50	0.53	112.00	66.00	0.54	113.00	0.50	0.85
Garlic	17.30	0.14	24.00	23.00	0.19	32.00	5.70	7.99
Tomatoes	209.10	1.70	419.00	215.00	1.75	431.00	5.90	11.84
Squash	21.80	0.18	44.00	24.00	0.20	48.00	2.20	4.40
Peas	52.20	0.42	105.00	60.00	0.49	120.00	7.80	15.62
Cabbage	28.20	0.23	57.00	33.00	0.27	66.00	4.80	9.62
Potatoes	102.40	0.83	282.00	18.00	0.15	50.00	-84.40	-232.10
Pepper	25.30	0.21	51.00	25.00	0.20	50.00	-0.30	-0.60
Total area cultivated in Winter Season	6363.00	51.79	11421.00	6363.00	51.79	11285.00	0.00	-136.00
Rice	1593.00	12.97	8266.00	1459.00	11.88	7571.00	-134.00	-695.33
Maize	1711.00	13.93	4507.00	1827.50	14.87	4814.00	116.50	306.86
Sorghum	367.50	2.99	991.00	351.00	2.86	947.00	-16.50	-44.50
Soya beans	17.80	0.14	47.00	18.00	0.15	48.00	0.20	0.53
Sesame	73.40	0.60	181.00	67.00	0.55	165.00	-6.40	-15.76
Peanut	132.10	1.08	454.00	132.00	1.07	454.00	-0.10	-0.34
Sunflower	35.70	0.29	75.00	32.00	0.26	68.00	-3.70	-7.82
Sugar cane	326.90	2.66	2553.00	321.00	2.61	2507.00	-5.90	-46.07
Cotton	536.40	4.37	1514.00	547.10	4.45	1544.00	10.70	30.20
Tomatoes	241.30	1.96	690.00	241.00	1.96	690.00	-0.30	-0.86
Potatoes	79.10	0.64	230.00	113.00	0.92	329.00	33.90	98.65
Cucumber	60.50	0.49	167.00	44.00	0.36	121.00	-16.50	-45.44
Squash	59.60	0.49	167.00	100.90	0.82	283.00	41.30	115.64
Eggplant	58.40	0.48	166.00	58.00	0.47	165.00	-0.40	-1.14
Pepper	59.60	0.49	169.00	39.00	0.32	111.00	-20.60	-58.50
Melon	157.20	1.28	459.00	159.00	1.29	464.00	1.80	5.26
Total area cultivated in Summer Season	5509.50	44.84	20637.00	5509.50	44.84	20278.00	0.00	-359.00
Maize	282.50	2.30	619.00	283.80	2.31	622.00	1.30	2.85
Green beans	7.70	0.06	19.00	3.70	0.03	9.00	-4.00	-10.13
Tomatoes	74.00	0.60	188.00	77.00	0.63	196.00	3.00	7.62
Potatoes	39.00	0.32	99.00	39.00	0.32	99.00	0.00	0.00
Cabbage	10.30	0.08	24.00	10.00	0.08	23.00	-0.30	-0.70
Total area cultivated in Nili Season	413.50	3.37	950.30	413.50	3.37	949.94	0.00	-0.36
The Grand Total	12286.00	100.00	33008.00	12286.00	100.00	32513.00	0.00	-495.00

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the second scenario.

However, Table (8) shows a summary of the results of solving linear programming models according to the second scenario, indicating an increase in the net revenue for

the total cultivated area from L.E. 29.720 million in 2006 to L.E. 29.994 billion for the cropping pattern according to the second scenario.

Table (8): A summary of the results obtained by solving the linear programming models according to the second scenario

Item	Cropping Pattern of 2006	Cropping Pattern Proposed According to Second Scenario	% of Change
Total Cropped Area (million feddans)	12.286	12.286	0
Total Net Revenue for the Total Cropped Area (L.E. billion)	29.720	29.994	0.915
Total Water Requirements (BCM)	33.008	32.580	-1.312

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the second scenario.

This result shows that the cropping pattern according to the second scenario increases the net revenue for the total cultivated area by about 0.915% compared to the cropping pattern in 2006. On the other hand, the total water irrigation requirements for the cropping pattern of 2006 reached about 33.008 BCM, compared to about 32.580 BCM for the cropping pattern according to the second scenario. This result shows that the cropping pattern according to the second scenario decreases the total water irrigation requirements by 1.312% compared to the cropping pattern in 2006, which means that the proposed cropping pattern according to the second scenario achieves the goal of this model.

The results of the third scenario: Maximizing the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops:

Table (9) illustrates the cropping pattern according to the third scenario compared to the cropping pattern of 2006, indicating that changes in the winter crops produced according to this scenario refer to an increase in the area cultivated by some crops i.e. wheat, broad bean, lentils, flax, sugar beets, garlic, tomatoes and cabbage. On the contrary, the rest of the areas cultivated by other winter crops decreased. However, the total net revenue for the area cultivated in winter season reached about L.E. 15.79 billion in 2006 compared to about L.E. 15.89 billion for the suggested cropping pattern according to this scenario, indicating an increase estimated at about L.E. 103.49 million for the suggested cropping pattern according to this scenario.

Table (9): The cropping pattern according to the third scenario compared to 2006

Crops	Cropping Pattern of 2006			Cropping Pattern Proposed According to Third Scenario			Changes in Cultivated Area	Changes in the Net Revenue for the Total Cultivated Area
	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Net Revenue for the Total Cultivated Area (L.E. millions)	Cultivated Area (Thousand feddans)	% Out of the Grand Total	Net Revenue for the Total Cultivated Area (L.E. millions)	(Thousand Feddans)	(L.E. Millions)
Wheat	3064.00	24.94	5709.00	3205.00	26.09	5971.00	141.00	262.70
Barley	214.50	1.75	110.00	85.00	0.69	43.00	-129.50	-66.21
Fenugreek	15.00	0.12	28.00	12.00	0.10	22.00	-3.00	-5.58
Broad bean	198.40	1.61	274.00	300.00	2.44	415.00	101.60	140.44
Lentils	1.50	0.01	1.00	4.00	0.03	3.00	2.50	1.81
Lupine	3.40	0.03	5.00	3.00	0.02	4.00	-0.40	-0.55
Chickpeas	15.20	0.12	15.00	14.00	0.11	14.00	-1.20	-1.22
Flax	15.60	0.13	24.00	16.00	0.13	25.00	0.40	0.61
Sugar beets	186.40	1.52	321.00	215.00	1.75	370.00	28.60	49.26
Short-season clover	470.20	3.83	817.00	469.00	3.82	815.00	-1.20	-2.09
Long-season clover	1657.00	13.49	6027.00	1603.00	13.05	5830.00	-54.00	-196.40
Onions	65.50	0.53	221.00	61.00	0.50	206.00	-4.50	-15.21
Garlic	17.30	0.14	117.00	18.00	0.15	121.00	0.70	4.72
Tomatoes	209.10	1.70	1677.00	215.00	1.75	1725.00	5.90	47.33
Squash	21.80	0.18	54.00	20.00	0.16	49.00	-1.80	-4.45
Peas	52.20	0.42	109.00	52.00	0.42	109.00	-0.20	-0.42
Cabbage	28.20	0.23	90.00	33.00	0.27	105.00	4.80	15.31
Potatoes	102.40	0.83	141.00	18.00	0.15	25.00	-84.40	-116.43
Pepper	25.30	0.21	48.00	20.00	0.16	38.00	-5.30	-10.13
Total area cultivated in Winter Season	6363.00	51.79	15788.00	6363.00	51.79	15892.00	0.00	104.00
Rice	1593.00	12.97	3232.00	1207.00	9.82	2449.00	-386.00	-783.12
Maize	1711.00	13.93	3219.00	2180.00	17.74	4101.00	469.00	882.28
Sorghum	367.50	2.99	443.00	351.00	2.86	423.00	-16.50	-19.88
Soya beans	17.80	0.14	12.00	22.00	0.18	15.00	4.20	2.93
Sesame	73.40	0.60	81.00	75.00	0.61	83.00	1.60	1.76
Peanut	132.10	1.08	320.00	145.00	1.18	351.00	12.90	31.25
Sunflower	35.70	0.29	23.00	40.00	0.33	26.00	4.30	2.78
Sugar cane	326.90	2.66	1393.00	270.50	2.20	1153.00	-56.40	-240.31
Cotton	536.40	4.37	1442.00	438.00	3.57	1178.00	-98.40	-264.55
Tomatoes	241.30	1.96	1067.00	265.00	2.16	1172.00	23.70	104.81

Potatoes	79.10	0.64	254.00	175.00	1.42	562.00	95.90	307.72
Cucumber	60.50	0.49	151.00	44.00	0.36	109.00	-16.50	-41.06
Squash	59.60	0.49	188.00	60.00	0.49	189.00	0.40	1.26
Eggplant	58.40	0.48	137.00	58.00	0.47	136.00	-0.40	-0.94
Pepper	59.60	0.49	61.00	39.00	0.32	40.00	-20.60	-21.13
Melon	157.20	1.28	604.00	140.00	1.14	538.00	-17.20	-66.09
Total area cultivated in Summer Season	5509.50	44.84	12627.00	5509.50	44.84	12524.00	0.00	-103.00
Maize	282.50	2.30	375.00	283.00	2.30	375.00	0.50	0.66
Green beans	7.70	0.06	21.00	4.00	0.03	11.00	-3.70	-9.98
Tomatoes	74.00	0.60	818.00	78.50	0.64	867.00	4.50	49.72
Potatoes	39.00	0.32	57.00	38.00	0.31	55.00	-1.00	-1.45
Cabbage	10.30	0.08	35.00	10.00	0.08	34.00	-0.30	-1.03
Total area cultivated in Nili Season	413.50	3.37	1305.00	413.50	3.37	1343.00	0.00	38.00
The Grand Total	12286.00	100.00	29720.00	12286.00	100.00	29759.00	0.00	39.00

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the third scenario.

Moreover, the changes in summer crops according to this scenario showed an increase in the area cultivated by some crops i.e. maize, soya beans, sesame, peanut, sunflower, potatoes, squash, and melon. On the contrary, the rest of the areas cultivated by other summer crops decreased. However, the total net revenue for the area cultivated in summer season reached about L.E. 12.63 billion in 2006 compared to about L.E. 12.52 billion for the suggested cropping pattern according to this scenario, indicating an increase estimated at about L.E. 103.00 million for the suggested cropping pattern according to this scenario.

However, the changes in Nili crops according to this scenario showed an increase in the area cultivated by tomatoes and maize only. On the contrary, the rest of the areas cultivated by other Nili crops decreased. However, the total net revenue for the area cultivated in Nili season reached about L.E. 1.30 billion in 2006 compared to about L.E. 1.34 billion for the suggested cropping pattern according to this scenario, indicating an increase estimated at about L.E. 38.00 million for the suggested cropping pattern according to this scenario.

Nevertheless, Table (10) shows a summary of the results of solving linear programming models according to the third scenario, indicating an increase in the net revenue for the total cultivated area from L.E. 29720 million in 2006 to reach about L.E. 29.759 billion for the cropping pattern according to the third scenario. This result shows that the cropping pattern according to the third scenario increases the net revenue for the total cultivated area by about 0.132% compared to the cropping pattern

in 2006, which means that the proposed cropping pattern according to the third scenario achieves the goal of this model.

On the other hand, the total water irrigation requirements for the cropping pattern of 2006 reached about 33.008 BCM, compared to about 31.595 BCM for the cropping pattern according to the third scenario. This result shows that the cropping pattern according to the third scenario decreases the total water irrigation requirements by about 4.280% compared to the cropping pattern in 2006.

Table (10): A summary of the results obtained by solving the linear programming models according to the third scenario:

Item	Cropping Pattern of 2006	Cropping Pattern Proposed According to Third Scenario	% of Change
Total Cropped Area (million feddans)	12.286	12.286	0
Total Net Revenue for the Total Cropped Area (L.E. billion)	29.720	29.759	0.132
Total Water irrigation Requirements (BCM)	33.008	31.595	-4.280

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the third scenario.

A comparison among the results of solving linear programming models for the cropping patterns:

In light of the results obtained from solving linear programming models for the cropping patterns according to the previous three scenarios, it can come up with some economic indicators that would help decision makers in the field of economic planning and directing economic resources available to the agricultural sector. Table (11) illustrates the most important economic indicators as follows:

A- In case of maximizing the total net revenue for the cropping pattern:

The results show that the total net revenue for the cropping pattern in 2006 reached about L.E. 29.72 million. However, the best crop combination is produced according to the second scenario since it achieves the highest total net revenue estimated at about L.E. 29.99 billion, indicating an increase of the total net revenue by about 0.96% compared to the cropping pattern in 2006.

B- In case of minimizing water irrigation requirements for the cropping pattern:

The results show that the total water irrigation requirements for the cropping pattern in 2006 reached about 33.01 BCM. However, the best crop combination is produced according to the third scenario since it achieves the least total water irrigation

requirements estimated at about 31.60 BCM, indicating a decrease of the total water irrigation requirements by about 4.28% compared to the cropping pattern in 2006.

Table (11): A summary of the results obtained by solving the linear programming models according to the three scenarios:

Item	Cropping Pattern of 2006	Cropping Pattern Proposed According to the Third Scenario		
		First Scenario	Second Scenario	Third Scenario
Objectives		Maximizing the total net revenue for the cropping pattern	Minimizing water irrigation requirements for the cropping pattern	Maximizing the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops
Total Net Revenue for the Total Cropped Area (L.E. billion)	29.72	29.91	29.99	29.76
% of Change	-	0.65	0.92	0.13
Total Water irrigation Requirements (BCM)	33.01	32.82	32.58	31.60
% of Change	-	-0.56	-1.31	-4.28

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the third scenario.

C- In case of maximizing the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops:

Table (12) illustrates the most important economic indicators of Self-Sufficiency Ratios (SSR) of some major crops and commodities. As for cereals, the results show that SSR of wheat for the cropping pattern in 2006 reached about 60.93%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of wheat estimated at about 64.00%. On the other hand, the results show that SSR of maize for the cropping pattern in 2006 reached about 58.10%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of maize estimated at about 75.00%. Nevertheless, the results show that SSR of rice for the cropping pattern in 2006 reached about 126.50%. However, the best crop combination is produced according to the first scenario since it achieves the highest SSR of rice estimated at about 125.76%.

Table (12): A comparison among the self-sufficiency ratios of some major crops and commodities (%)

Crops	Cropping Pattern of 2006	The Cropping Pattern Proposed According to Third Scenario		
		First Scenario	Second Scenario	Third Scenario
Objectives		Maximizing the total net revenue for the cropping pattern	Minimizing water irrigation requirements for the cropping pattern	Maximizing the total net revenue for the cropping pattern in case of achieving higher self-sufficiency ratios for the major crops
Cereals				
Wheat	60.93	60.93	61.43	64.00
Maize	58.10	59.30	61.53	75.00
Rice	126.50	125.76	115.86	70.00
Pulses				
Broad bean	42.75	42.66	42.66	60.00
Lentils	1.82	2.43	2.43	40.00
Vegetable oils				
Soya bean oil	2.66	2.69	2.69	3.29
Cotton-seed oil	73.04	72.99	74.5	59.64
Sunflower oil	9.07	7.96	7.96	9.94
Sweeteners				
Sugar of Sugar beet	102.22	99.29	69.93	114.77
Sugar of Sugar cane	79.50	78.63	78.63	66.26

Source: compiled and calculated from Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics and Statistics, Records of Statistics Sector, 2007 and from the cropping pattern obtained by the third scenario.

As for pulses, the results show that SSR of broad bean for the cropping pattern in 2006 reached about 42.75%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of broad bean estimated at about 60.00%. On the other hand, the results show that SSR of lentil for the cropping pattern in 2006 reached about 1.82%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of lentil estimated at about 40.00%.

As for vegetable oils, the results show that SSR of soya bean oil produced according to the cropping pattern in 2006 reached about 2.66%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of soya bean oil estimated at about 3.29%. On the other hand, the results show that SSR of cotton-seed oil produced according to the cropping pattern in 2006 reached about 73.04%. However, the best crop combination is produced according to the second scenario since it achieves the highest SSR of cotton-seed oil estimated at

about 74.5%. Nevertheless, the results show that SSR of sunflower oil produced according to the cropping pattern in 2006 reached about 9.07%. However, the best crop combination is produced according to the first scenario since it achieves the highest SSR of sunflower oil estimated at about 9.94%.

As for sweeteners, the results show that SSR of sugar of sugar beet produced according to the cropping pattern in 2006 reached about 102.22%. However, the best crop combination is produced according to the third scenario since it achieves the highest SSR of sugar of sugar beet oil estimated at about 114.77%. On the other hand, the results show that SSR of sugar of sugar cane produced according to the cropping pattern in 2006 reached about 79.50%. However, the best crop combination is produced according to the first and the second scenarios since they achieve the highest SSR of sugar of sugar cane estimated at about 78.63%.

CONCLUSION

It is already clear that the best combination of crops produced according to the third scenario represents the best solution of the linear programming models, since it provides high total net revenue, estimated at L.E. 29.76 billion, indicating an increase of about 0.13%. On the other hand, this combination achieves the most savings in the total water irrigation requirements estimated at 31.60 BCM, indicating an increase of about 4.28%. Moreover, the combination of crops produced according to the third scenario achieves the highest self-sufficiency ratios of some major crops and commodities i.e. wheat, maize, broad bean, lentils, soya bean oil, sunflower oil and sugar of sugar beet.

REFERENCES

1. Abo Elenein, R.; El-Wardani M.A.; Enas, Abbas M. and El-Dash W. (2008); The National Report of Egypt, Information Products for the Nile Basin Water Resources Management, the National Farming Systems Survey Consultancy, Food and Agriculture Organization of the United Nations; FAO, May.
2. Abu-Zeid, M., (1995); Egypt's Efforts towards Management of Agricultural Water Demands, National Water Research Center, MPWWR, Egypt, 1995.
3. Attia B. Bayoumi, (2004); Water as a human right: Water as a Basic Human Right in Egypt, Global Issue Papers, No. 11, Supplement-1, Ministry of Water Resources and Irrigation, September 2004.
4. El-Fellaly, S. H. and Enas, Abbas M. (2003); Egypt's Experience with Regard to Water Demand Management (WDM) in Agriculture, Food and Agriculture Organization; FAO, the Second Regional Conference on Water Demand Management and Pollution Control, Sharm El Sheikh, Egypt.
5. Enas, Abbas M.; (2002); M.Sc. Thesis; Economic Efficiency of Water Resources in the Egyptian Agricultural Sector, Faculty of Agriculture, Menoufia University, Egypt.

6. Enas, Abbas M.; (2008); Ph.D. Thesis; An Economic Study on the Optimum Use of Agricultural Land Resources in Egypt in the Light of National and International Changes, Faculty of Agriculture, Cairo University, Egypt.
7. Food and Agriculture Organization of the United Nations; (FAO) (2003); Review of World Water Resources by Country, ISSN 1020-1203, Rome.
8. Mc. Carl, Bruce A.; and Spreen, Thomas H., (2002); Applied Mathematical Programming Using Algebraic Systems, Texas A&M University.
9. Ministry of Agriculture and Land Reclamation; (MALR) (2003). The Strategy of Agricultural Development in Egypt until the Year 2017, FAO, May.
10. Ministry of Agriculture and Land Reclamation; (MALR) (2007). Central Department of Agrarian Economics and Statistics, Records of Statistics Sector.
11. Ministry of Water Resources and Irrigation; (MWRI) (2005). Ministry of Irrigation and Water Resources, Water for the Future: National Water Resources Plan 2017, NWRP Project, January.
12. Nassar, Saad Z. (1999); Motivations and Future of the Economic Reform in Egyptian Agriculture, Egyptian Agriculture Profile Montpellier CIHEAM-IAMM, ISBN 2-85352-145-1.
13. Policy Analysis Tools and Practices Course; (1998). Module VI: Linear Programming, Participant Guide, MALR Policy Analysis Courses, Institute of International Education Development Training 2 Project (IIE/DT2) And United States Agency of International Development (USAID).
14. The Central Authority for Public Mobilization and Statistics (CAPMAS) (2007); Records of Water Resources and Irrigation, July.
15. Siam, Gamal M. and Hoda Moussa A. (2003); Food Security in Egypt under Economic Liberalization Policies and WTO Agreement, International Conference on Agricultural Policy Reform and WTO Where Are We Heading?, Capri, Italy, June.
16. Zaragoza (2007); Water Demand Management in the Mediterranean: Progress and Policies, Monitoring Progress and Promotion of Water, Demand Management Policies, National Report of Egypt, 19-21 March.