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An economic study of the optimal crop composition in light of the available water resources in Egypt

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Abstract: The research aimed at trying to reach the optimal crop composition within the limits of Egypt's water potential, according to the two goals of maximizing the net yield of crop structure and minimizing water needs, by using linear programming for each goal separately once, and for the two goals combined again, and the results showed that the first model (The net return maximization model) achieved the highest net return, amounting to about 75,867.77 million pounds, an increase of about 583.18 million pounds, or about 0.77% of the total net return of the current crop composition, which amounts to about 75,284.59 million pounds, followed by the third model (the model for maximizing net returns and minimizing needs water together), where the total net yield amounted to about 75626.18 million pounds, an increase of about 341.59 million pounds, or about 0.45% of the total net yield of the current cropping structure, while the second model (the model of reducing water needs) has achieved a loss compared to the current cropping structure, as it amounted The total net return is about 70,627.04 million pounds, a decrease of about 4,657.55 million pounds, or about 6.19% over the total net return of the current crop composition. As for the reduction of water needs for the cropping structure, the second model (the water needs reduction model) achieved the highest reduction of water needs, as its water needs amounted to about 36,691.25 million m3, a decrease of about 604.19 million m3, or about 1.62% of the total water needs of the current cropping composition, The amount is about 37,295.44 million m3, followed by the third model (the model of maximizing net yield and minimizing water needs together), as the total water needs for it amounted to about 36989.44 million m3, with a decrease of about 306.00 million m3, or about 0.82% of the total water needs for the current crop structure, followed by The first model (net yield maximization model), where the total water needs amounted to about 37,003.94 million cubic meters, with a decrease of about 291.50 million cubic meters, or about 0.78% of the total water needs for the current crop structure.
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Keywords: Crop structure, single-objective linear programming, multi-objective linear programming, maximizing net yield, minimizing water requirements.

Introduction:

The issue of water resources is one of the most important issues facing the Egyptian society in recent times, as water resources are under unprecedented pressure, due to the stability and limitations of these resources on the one hand and the growing needs required of them on the other hand, due to the continuous population increase and meeting the requirements of development plans and programs. Economic in the field of agriculture and the challenges of food security [9], and water is considered one of the most basic and indispensable human needs, and the management of water resources is of great importance for sustainable economic development and poverty alleviation, as the use of water in agriculture is one of the important issues for Egyptian food security, rationalizing the use of irrigation water and raising Its efficient use has become more important in Egyptian agriculture, especially in light of the scarcity and limited Egyptian water resources [16].

Water resources, along with its impact on the nature and quantity of production, are considered the main determinant of agricultural production and its expansion [4]. The process of developing water resources will remain one of the main and effective pillars of sustainable agricultural development plans, especially at a time when the water supply problem is considered one of the most complex problems at the international and local levels [6].

The agricultural sector is one of the economic sectors that use the most water resources, as it consumes about 85% of the total Egyptian water resources, amounting to about 59 billion m3, and the volume of demand for water resources used in the agricultural sector is increasing due to the desire to increase agricultural development rates, especially when reclaiming new lands in order to increase the agricultural area [10]. Therefore, directing agricultural production by reconsidering the crop structure depends to a large extent on the optimal use of agricultural productive resources. Especially the aquatic ones, and the crop structure is defined as the method of distributing the area of agricultural lands to the agricultural crops that are successive during the agricultural year [1].

The optimum cropping composition is a relative concept due to the lack of ease in knowing what is optimal specifically and the phenomenon of conflicting goals [2], as there are many proposals made regarding improving the pattern of cropping structure in light of the goals to be achieved or the specific productive resources. From an economic point of view, the most appropriate cropping structure is which would maximize the economic return in light of the various available possibilities and other determinants [11].

The study Problem:

Given the importance of the net return of the acre for the farmer, and in light of his desire to grow crops that achieve the largest net return for him, the matter necessitated estimating the net return of the current crop structure, and comparing it with the optimal crop structure, and the extent to which the net return of farmers can be increased and thus increase their income, which benefits them. Also, given the importance of water in Egyptian agriculture, and in light of the difficulty of providing new sources of water, and with the need for more water to be used in adding new agricultural areas, the matter necessitated estimating the amount of water used in the current crop structure, and comparing it with the optimal crop structure, and the extent of The possibility of providing quantities of water that can be used in horizontal agricultural expansion.

Purpose of the study:

The farmer aims to achieve the largest net return, and the state aims to provide water for use in agriculture. Therefore, the research aims to try to reach the optimal crop composition within the limits of Egypt's water potential, according to the two objectives of maximizing the net crop structure return and minimizing water needs, using Linear programming for each goal separately once, and for the two goals combined again.

Method and data sources:

To analyze the data related to the subject of the study, some mathematical and statistical methods were used, such as arithmetic averages and percentages, in addition to using the linear programming method with one goal and multiple goals.

The study used secondary statistical data for the time period (2017-2021) available from the economic sector of the Egyptian Ministry of Agriculture and Land Reclamation, in addition to scientific references related to the subject of the study.

Results:

In this part, the research deals with the current crop composition of the most important agricultural crops in Egypt, the total net yield of the crop and its water needs during the period (2017-2021) as follows:

First: The current crop composition, the total net crop yield and its water needs for the most important agricultural crops in Egypt for the period (2017-2021):

It can be seen from Table (1) that the study included 10 winter crops, which are crops that are grown in October and November and are harvested at the beginning of spring, 11 summer crops, which are crops that are grown from the end of February to the end of May, 4 Nile crops, which are crops that are grown in July and August and are harvested in October and November, with a total of 25 crops whose total area is about 11.56 million feddans, representing about 71.36% of the total crop area, which is about 16.20 million feddans for the average period (2017-2021).

From the total net yield of each of the study crops in the same previous table, it was found that the sustainable alfalfa crop had the highest net yield, amounting to about 24.75 billion pounds, representing about 32.88% of the total net yield of the cropped area, which amounted to about 75.28 billion pounds, while the lowest The net yield of the Nile potato crop amounted to about 60.95 million pounds, representing about 0.08% of the total net yield of the cropped area.

As it was clear from the total water needs for each of the study crops in the same previous table as well, that the rice crop had the highest water requirement, reaching about 7.44 billion m3, representing about 19.96% of the total water needs for the cropped area, which amounted to about 37.30 billion m3, while The lowest water requirement was for the Nile tomato crop, which amounted to about 36.22 million cubic meters, representing about 0.10% of the total water requirements for the cropped area.

Second: Estimating the optimal crop composition in light of the available resources in Egypt, using the linear programming model:

In this part, the optimal cropping structure model is estimated in light of the limited resources available in Egypt, and the linear programming method has been used, which is one of the mathematical methods used in the field of economic planning and resource orientation, in order to achieve a specific goal or several goals [13].

Description of the objective functions of the one-objective linear programming model:

(a): Description of the objective functions in the case of maximizing the net return per feddan [7]:

$$\text{Max } G_1 = \sum_{j=1}^{n} X_j R_j$$

Where X represents crop area, R represents net yield per feddan.

(B): Description of the objective function in the case of low water needs [15]:

$$\text{Min } G_2 = \sum_{j=1}^{n} X_j W_j$$

Where X represents the crop area, W represents the amount of water used to irrigate the feddan.

Subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (i = 1,2,\dots,m)$$

$$X_j \geq 0 \qquad (j = 1,2,\dots,n)$$

Where:

n = number of variables in the model, m = number of model constraints, a_{ij} = form parameters, b_i = It expresses the available resources or requirements for each constraint of the model and must be positive, with a non-negative condition.

Description of the objective functions of the multi-objective linear programming model:

Most decision cases are not characterized by the existence of a single goal, but in many cases the decision maker has several goals that may complement each other or may conflict with each other [12], and programming goals is a successful method in dealing with the conflict or contradiction of multiple goals, which requires the achievement of more than one goal At the same time [8], it is an extension of the linear programming method and its main idea goes to addressing the issue of competing goals that are on the ground [3].

Table (1) the current crop composition and the total net crop yield and its water requirements for the most important agricultural crops in Egypt for the average period (2017-2021).

The crop	Current crop composition		The total net yield of the crop		The total water requirement of the crop	
	Thousand feddans	(%)	one million pound	(%)	million m^3	(%)
Wheat	3210.67	27.76	10421.84	13.84	6694.25	17.95
Barley	134.24	1.16	365.12	0.48	193.70	0.52
Perennial clover	1467.09	12.69	24752.81	32.88	3321.50	8.91
Clover molestation	162.71	1.41	1099.77	1.46	229.26	0.61
Municipal beans	104.23	0.90	767.88	1.02	208.26	0.56
Winter onions	203.75	1.76	3320.48	4.41	420.94	1.13
The Garlic	39.16	0.34	617.66	0.82	100.57	0.27
Sugar beet	564.43	4.88	2055.08	2.73	1636.28	4.39
Winter potatoes	283.46	2.45	2748.18	3.65	572.03	1.53
Winter tomato	178.62	1.54	3400.31	4.52	360.45	0.97
Summer white maize	1429.85	12.36	4697.06	6.24	5167.48	13.86
Summer yellow maize	806.95	6.98	2650.84	3.52	2916.33	7.82
Sorghum	361.27	3.12	507.58	0.67	1506.49	4.04
The rice	1152.64	9.97	3774.90	5.01	7442.61	19.96
Cotton	242.72	2.10	1928.20	2.56	782.54	2.10
Peanuts	152.37	1.32	558.76	0.74	479.22	1.28
Sesame	79.47	0.69	561.98	0.75	258.58	0.69
Soybean	35.57	0.31	140.92	0.19	138.68	0.37
Summer potatoes	130.44	1.13	1025.78	1.36	345.54	0.93
Summer tomato	190.41	1.65	3893.84	5.17	504.39	1.35
Sugar cane	332.07	2.87	5003.99	6.65	3375.18	9.05

Indigo white maize	140.83	1.22	405.31	0.54	317.72	0.85
Indigo Yellow Maize	99.52	0.86	286.41	0.38	224.51	0.60
Indigo potatoes	39.42	0.34	60.95	0.08	62.72	0.17
Indigo tomato	22.77	0.20	238.93	0.32	36.22	0.10
Total	11564.67	100.00	75284.59	100.00	37295.44	100.00

Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

The general formula for the goal programming model [5]:

$$\text{Min a} = P_1\left(d_1^-, d_1^+\right), P_2\left(d_2^-, d_2^+\right) \ldots \ldots P_k\left(d_k^-, d_k^+\right)$$

Subject to:

$$\sum_{i=1}^{n} C_{ij}X_{ij} + d_i^- - d_i^+ = b_i \qquad j = 1,2,\ldots\ldots m$$

$$d_i^-, d_i^+ \geq 0 \qquad i = 1,2,\ldots\ldots n$$

Whereas:

a = represents the achievement function, k = the number of goals, X_{ij} = the decision variables, b_i = the value of the objective function (i) in the objective constraints, while in non-objective constraints it represents the available resources.

C_{ij} = coefficient of variables, n = number of variables, m = number of constraints, P_k = goals.

d_i- = a deflection variable indicating the lowest achievement of the objective function i.

d_i+ = a deflection variable that indicates the highest achievement of the objective function i.

Components of the linear programming model:

(a): Alternative Activities:

The linear programming analysis models for crop composition for the average period (2017-2021) included 25 cropping activities, with an area of about 11.56 million feddans.

(b): Limitations of the Linear Programming Paradigm:

The water standards per feddan were adhered to for each of the crops under study. The total amount of water used in irrigating the crops of the current model was about 31.47 billion m3. The production requirements for the crops under study were also adhered to, with a commitment to the total crop installation area for the crops, subject of study.

Minor and major limits were set for the area of each crop separately, meaning that the area of any crop is not more than the maximum area and not less than the minimum area that was cultivated during the study period (2017-2021). Summer yellow, indigo and soybeans, while adhering to the area allocated for rice cultivation [14].

Linear Programming Analysis Results:

1- Maximizing the total net crop yield for the average period (2017-2021):

Table (2) shows the maximization of the total net yield of cropping installation, for the average period (2017-2021), as it was found that the total net yield of optimal cropping amounted to about 75.86 billion pounds, an increase of about 0.58 billion pounds, or about 0.77%, compared to the current total net crop yield, which amounts to about 75.28 billion pounds, The previous table also shows the area of crops that must be increased, which are: wheat, perennial alfalfa, sugar beet, winter tomato, summer yellow maize, soybeans, summer tomato, and indigo yellow maize, where the increase amounted to about 208.69, 88.72, 118.71, 14.38, 40.05, 14.27, 28.59, and 57.48 thousand feddans, representing about 6.50%, 6.05%, 21.03%, 8.05%, 4.96%, 40.12%, 15.01%, and 57.76% of the total area of each current crop, respectively, as the same previous table shows the area The crops that must be reduced are: barley, alfalfa, local beans, winter onions, garlic, winter potatoes, summer white maize, sorghum, rice, cotton, peanuts, sesame, summer potatoes, sugar cane, white maize, indigo, Indigo potato, indigo tomato, where the decrease reached about 81.06, 35.15, 26.23, 16.75, 8.16, 52.46, 64.85, 3.27, 76.64, 59.72, 12.70, 17.47, 29.44, 6.07, 39.83, 34.31, 6.77 thousand feddans, representing about 60.38% , 21.60%, 25.17%, 8.22%, 20.84%, 18.51%, 4.54%, 0.91%, 6.65%, 24.60%, 8.33%, 21.98%, 22.57%, 1.83%, 28.28%, 87.04%, 29.73% out of total The area of each current crop, respectively.

Table (2) the optimal crop composition of the most important agricultural crops according to the net return maximization model in Egypt for the average period (2017-2021).

The crop	Current crop composition (thousand feddans)	Optimum crop composition (thousand feddans)	The amount of change (1) (thousand feddans)	% (2)
Wheat	3210.67	3419.36	208.69	6.50
Barley	134.24	53.18	-81.06	-60.38
Perennial clover	1467.09	1555.81	88.72	6.05
clover molestation	162.71	127.56	-35.15	-21.60
Municipal beans	104.23	78.00	-26.23	-25.17
Winter onions	203.75	187.00	-16.75	-8.22
The Garlic	39.16	31.00	-8.16	-20.84
Sugar beet	564.43	683.14	118.71	21.03
Winter potatoes	283.46	231.00	-52.46	-18.51
Winter tomato	178.62	193.00	14.38	8.05
Summer white maize	1429.85	1365.00	-64.85	-4.54
Summer yellow maize	806.95	847.00	40.05	4.96
Sorghum	361.27	358.00	-3.27	-0.91
The rice	1152.64	1076.00	-76.64	-6.65
Cotton	242.72	183.00	-59.72	-24.60
Peanuts	152.37	139.67	-12.70	-8.33
Sesame	79.47	62.00	-17.47	-21.98
Soybean	35.57	49.84	14.27	40.12
Summer potatoes	130.44	101.00	-29.44	-22.57
Summer tomato	190.41	219.00	28.59	15.01
Sugar cane	332.07	326.00	-6.07	-1.83
Indigo white maize	140.83	101.00	-39.83	-28.28
Indigo Yellow Maize	99.52	157.00	57.48	57.76
Indigo potatoes	39.42	5.11	-34.31	-87.04
Indigo tomato	22.77	16.00	-6.77	-29.73
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total net revenue (million pounds)	75284.59	75867.77	583.18	0.77

(1) The amount of change = the expected - the actual.
(2) Change rate = (expected - actual) / actual * 100.
Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

2 -Reducing the total water needs for the cropping structure for the average period (2017-2021):

This part of the study aims to rationalize the use of water resources by reducing irrigation water needs to achieve the largest surplus of available water resources that can be exploited in horizontal agricultural expansion.

Table (3) shows the decrease in the total water requirements for cropping composition, for the average period (2017-2021), as it was found that the total water needs for optimal cropping composition amounted to about 36.69 billion m3, with a decrease of about 0.60 billion m3, representing about 1.62% of the total needs, water for the current crop composition, which amounts to about 37.29 billion m3, as the previous table shows that the model agreed with the previous model in increasing the area of some crops, namely: wheat, sugar beet, summer yellow maize, soybeans, indigo yellow maize, and also in reducing the area of some crops, The other crops are: winter onions, garlic, winter potatoes, summer white maize, sorghum, rice, cotton, peanuts, sesame, summer potatoes, sugar cane, white indigo maize, and differed with the previous model in increasing the area of some crops, They are: barley, alfalfa stalks, indigo potatoes, indigo tomatoes, where the increase amounted to about 139.76, 46.29, 12.58, and 6.23 thousand feddans, representing about 104.11%, 28.45%, 31.91%, and 27.36% of the total area of each current crop, respectively, Also in reducing the area of some other crops, namely: perennial alfalfa, beans, winter tomatoes, summer tomatoes, where the decrease reached about 222.62, 0.04, 9.62, 24.41 thousand feddans, representing about 15.17%, 0.04%, 5.39%, 12.82% of the total The area of each current crop, respectively.

Table (3) the optimal crop composition of the most important agricultural crops according to the model of reducing water needs in Egypt for the average period (2017-2021).

The crop	Current crop composition (thousand feddans)	Optimum crop composition (thousand feddans)	The amount of change (1) (thousand feddans))	% (2)
Wheat	3210.67	3419.36	208.69	6.50
Barley	134.24	274.00	139.76	104.11
Perennial clover	1467.09	1244.47	-222.62	-15.17
Clover molestation	162.71	209.00	46.29	28.45
Municipal beans	104.23	104.19	-0.04	-0.04
Winter onions	203.75	187.00	-16.75	-8.22
The Garlic	39.16	31.00	-8.16	-20.84
Sugar beet	564.43	683.14	118.71	21.03
Winter potatoes	283.46	231.00	-52.46	-18.51
Winter tomato	178.62	169.00	-9.62	-5.39
Summer white maize	1429.85	1365.00	-64.85	-4.54
Summer yellow maize	806.95	847.00	40.05	4.96
Sorghum	361.27	358.00	-3.27	-0.91
The rice	1152.64	1076.00	-76.64	-6.65
Cotton	242.72	183.00	-59.72	-24.60
Peanuts	152.37	139.67	-12.70	-8.33
Sesame	79.47	62.00	-17.47	-21.98
Soybean	35.57	49.84	14.27	40.12
Summer potatoes	130.44	101.00	-29.44	-22.57
Summer tomato	190.41	166.00	-24.41	-12.82
Sugar cane	332.07	326.00	-6.07	-1.83
Indigo white maize	140.83	101.00	-39.83	-28.28
Indigo Yellow Maize	99.52	157.00	57.48	57.76
Indigo potatoes	39.42	52.00	12.58	31.91
Indigo tomato	22.77	29.00	6.23	27.36
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total water needs (million m^3)	37295.44	36691.25	-604.19	-1.62

(1) The amount of change = the expected - the actual.
(2) Change rate = (expected - actual) / actual * 100.
Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

Table (4) shows the area that can be cultivated from one of the strategic crops using the amount of water saved as a result of the optimal cropping composition of the most important agricultural crops according to the model for reducing water needs in Egypt for the average period (2017-2021), where one of these crops can be added to The total crop area is: wheat, sugar beet, summer yellow maize, soybeans, where the increase amounted to about 289.78, 208.41, 167.18, 154.96 thousand feddans, representing about 9.03%, 36.92%, 20.72%, 435.65% of the total area of the current crop. The amounts are about 3210.67, 564.43, 806.95, and 35.57 thousand feddans, giving a production quantity of about 799.79, 4280.81, 548.35, and 189.05 thousand tons, respectively.

Table (4) the area that can be cultivated from one of the strategic crops using the amount of water saved as a result of the optimal crop composition of the most important agricultural crops according to the model of reducing water needs in Egypt for the average period (2017-2021).

Statement	Wheat	Sugar beet	Summer yellow maize	soybean
The amount of water saved (million m^3)	604.19	604.19	604.19	604.19
Water requirements per feddans (m^3)	2085	2899	3614	3899
Area that can be added (thousand feddans)	289.78	208.41	167.18	154.96
Total current crop area (thousand feddans)	3210.67	564.43	806.95	35.57
Area Increase Percentage(%)	9.03	36.92	20.72	435.65
Feddans productivity (tons)	2.76	20.54	3.28	1.22
The amount of production that can be added (thousands of tons)	799.79	4280.81	548.35	189.05

Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

3- Maximizing the total net yield and minimizing the total water requirements together for the cropping structure for the average period (2017-2021):

This part of the study aims to rationalize the use of water resources by reducing irrigation water needs to achieve the largest surplus of available water resources that can be exploited in horizontal agricultural expansion.

Table (5) shows the maximization of the total net yield and the minimization of the total water requirements together for cropping structure, for the average period (2017-2021), Where it was found that the total net return of optimal cropping installation amounted to about 75.62 billion pounds, an increase of about 0.34 billion pounds, or about 0.45% over the current total net return of cropping installation, which is about 75.28 billion pounds. It was also found that the total water needs for optimal cropping composition amounted to about 36.99 billion m3, a decrease of about 0.31 billion m3, representing about 0.82% of the total water needs for the current cropping structure, which is about 37.30 billion m3. The previous table also shows that the model agreed with the previous model in increasing the area of some crops, namely: wheat, sugar beet, summer yellow maize, soybeans, indigo yellow maize, and also in reducing the area of some other crops, namely: winter onions, garlic, potatoes winter, winter tomatoes, summer white maize, sorghum, rice, cotton, peanuts, sesame, summer potatoes, summer tomatoes, sugar cane, indigo white maize, It also differed with the previous model in increasing the area of permanent alfalfa, as the increase amounted to about 165.72 thousand acres, representing about 11.30% of the total area of the current crop. It also differed in reducing the area of some other crops, namely: barley, alfalfa, local beans, indigo potatoes, indigo tomatoes, as the decrease reached about 81.06, 35.15, 26.23, 34.31, and 6.77 thousand feddans, representing about 60.38%, 21.60%, and 25.17%, 87.04%, and 29.73% of the total area of each current crop, respectively.

Table (6) shows the area that can be cultivated from one of the strategic crops using the amount of water saved as a result of the optimal cropping composition of the most important agricultural crops according to the model of total net yield maximization and total water requirement minimization together in Egypt for the average period (2017-2021), Where one of these crops can be added to the total crop area, namely: wheat, sugar beet, summer maize, soybeans, where the increase in the area of any of them reached about 146.76, 105.55, 84.67, 78.48 thousand feddans, representing about 4.57%, 18.70% , 10.49%, 220.64% of the total area of the current crop, which amounts to about 3210.67, 564.43, 806.95, 35.57, giving an amount of production of about 405.06, 2168.07, 277.72, and 95.75, respectively.

Third: Comparison between the achieved objectives of the three models:

Table (7) presents a comparison between the results of the three models under study in Egypt for the average period (2017-2021). By comparing the results of these models, it is clear that the three models achieved the cropped area in the current cropping structure, which is 11564.67 thousand feddans.

With regard to the net cropping yield, the first model (the net yield maximization model) achieved the highest net yield, amounting to about 75867.77 million pounds, an increase of about 583.18 million pounds, or about 0.77% of the current total net yield of cropping installation, which amounts to about 75284.59 million pounds, followed by the model The third (the model of maximizing net yield and minimizing water needs together), where the total net yield amounted to about 75,626.18 million pounds, an increase of about 341.59 million pounds, or about 0.45% of the total net yield of the current crop composition, while the second model (the model of reducing water needs) has It achieved a loss from the current cropping structure, as the total net return amounted to about 70627.04 million pounds, a decrease of about 4657.55 million pounds, or about 6.19% over the total net return from the current cropping structure.

As for the reduction of water needs for the cropping structure, the second model (the water needs reduction model) achieved the highest reduction of water needs, as its water needs amounted to about 36691.25 million m3, a decrease of about 604.19 million m3, or about 1.62% of the total water needs of the current cropping structure. The amount is about 37295.44 million m3, followed by the third model (the model of maximizing net yield and minimizing water needs together), as the total water needs for it amounted to about 36989.44 million m3, with a decrease of about 306.00 million m3, or about 0.82% of the total water needs for the current crop structure, followed by The first model (net yield maximization model), where the total water needs amounted to about 37003.94 million cubic meters, with a decrease of about 291.50 million cubic meters, or about 0.78% of the total water needs for the current crop structure.

Table (5), the optimum cropping composition of the most important agricultural crops according to the model of maximizing total net yield and minimizing total water requirements together in Egypt for the average period (2017-2021).

The crop	Current crop composition (thousand feddans)	Optimum crop composition (thousand feddans)	The amount of change (1) (thousand feddans)	% (2)
Wheat	3210.67	3419.36	208.69	6.50
Barley	134.24	53.18	-81.06	-60.38
Perennial clover	1467.09	1632.81	165.72	11.30
Clover molestation	162.71	127.56	-35.15	-21.60
Municipal beans	104.23	78.00	-26.23	-25.17
Winter onions	203.75	187.00	-16.75	-8.22
The Garlic	39.16	31.00	-8.16	-20.84
Sugar beet	564.43	683.14	118.71	21.03
Winter potatoes	283.46	231.00	-52.46	-18.51
Winter tomato	178.62	169.00	-9.62	-5.39
Summer white maize	1429.85	1365.00	-64.85	-4.54
Summer yellow maize	806.95	847.00	40.05	4.96
Sorghum	361.27	358.00	-3.27	-0.91
The rice	1152.64	1076.00	-76.64	-6.65
Cotton	242.72	183.00	-59.72	-24.60
Peanuts	152.37	139.67	-12.70	-8.33
Sesame	79.47	62.00	-17.47	-21.98
Soybean	35.57	49.84	14.27	40.12
Summer potatoes	130.44	101.00	-29.44	-22.57
Summer tomato	190.41	166.00	-24.41	-12.82

Sugar cane	332.07	326.00	-6.07	-1.83
Indigo white maize	140.83	101.00	-39.83	-28.28
Indigo Yellow Maize	99.52	157.00	57.48	57.76
Indigo potatoes	39.42	5.11	-34.31	-87.04
Indigo tomato	22.77	16.00	-6.77	-29.73
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total net revenue (million pounds)	75284.59	75626.18	341.59	0.45
Total water needs (million m^3)	37295.44	36989.44	-306.00	-0.82

(1) The amount of change = the expected - the actual.
(2) Change rate = (expected - actual) / actual * 100.
Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

Table (6) the area that can be cultivated from one of the strategic crops using the amount of water saved as a result of the optimal cropping composition of the most important agricultural crops according to the model of total net yield maximization and total water requirement minimization together in Egypt for the average period (2017-2021).

Statement	Wheat	Sugar beet	Summer yellow maize	soybean
The amount of water saved (million m^3)	306	306	306	306
Water requirements per feddans (m^3)	2085	2899	3614	3899
Area that can be added (thousand feddans)	146.76	105.55	84.67	78.48
Total current crop area (thousand feddans)	3210.67	564.43	806.95	35.57
Area Increase Percentage (%)	4.57	18.70	10.49	220.64
Feddans productivity (tons)	2.76	20.54	3.28	1.22
The amount of production that can be added (thousands of tons)	405.06	2168.07	277.72	95.75

Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

Table (7) Comparison of the results of the three models under study in Egypt for the average period (2017-2021)

Statement	Current crop composition (thousand feddans)	Optimum crop composition (thousand feddans)	The amount of change (1) (thousand feddans)	% (2)
Net return maximization model				
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total net revenue (million pounds)	75284.59	75867.77	583.18	0.77
Total water needs (million m3)	37295.44	37003.94	-291.50	-0.78
Water Requirements Reduction Model				
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total net revenue (million pounds)	75284.59	70627.04	-4657.55	-6.19
Total water needs (million m3)	37295.44	36691.25	-604.19	-1.62

The model of maximizing net yield and minimizing water requirements together				
Total area (thousand feddans)	11564.67	11564.67	0.00	0.00
Total net revenue (million pounds)	75284.59	75626.18	341.59	0.45
Total water needs (million m3)	37295.44	36989.44	-306.00	-0.82

(1) The amount of change = the expected - the actual.
(2) Change rate = (expected - actual) / actual * 100.
Source: Collected and calculated from the Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Bulletin of Agricultural Statistics, Bulletin of Water Resources, separate issues, and records of the Statistics Department, 2022.

Conclusion:

The issue of water resources is considered one of the most important issues facing the Egyptian society in recent times, as water resources are under unprecedented pressure, due to the stability and limitations of these resources in addition to the growing needs required of them, as the use of water in agriculture is considered one of the important issues for security Egyptian food, rationalizing the use of irrigation water and raising the efficiency of its use has become more important in Egyptian agriculture, especially in light of the scarcity and limited Egyptian water resources, and at a time when the water supply problem is considered one of the most complex problems at the international and local levels.

Water resources, in addition to their impact on the nature and quantity of production, are the main determinants of agricultural production and its expansion. The agricultural sector is one of the most economic sectors that use water resources, as it consumes about 85% of the total Egyptian water resources, amounting to about 59 billion m3.

The problem of the study was represented in the difficulty of providing new sources of water, and in light of the need for more water to be used in adding new agricultural areas, the matter necessitated estimating the amount of water used in the current crop structure, and comparing it with the optimal crop structure, and the possibility of providing quantities of water Can be used in horizontal agricultural expansion.

The research aimed at trying to reach the optimal crop composition within the limits of Egypt's water potential, according to the two goals of maximizing the net yield of crop structure and minimizing water needs, by using linear programming for each goal separately once, and for the two goals combined again.

The results showed that the first model (the net return maximization model) achieved the highest net return, amounting to about 75867.77 million pounds, an increase of about 583.18 million pounds, or about 0.77% of the total net return of the current crop composition, which amounts to about 75284.59 million pounds, followed by the third model. (Model of maximizing net yield and minimizing water needs together), where the total net yield amounted to about 75,626.18 million pounds, an increase of about 341.59 million pounds, or about 0.45% of the total net yield of the current cropping structure, while the second model (the model of minimizing water needs) achieved A loss from the current cropping composition, as the total net yield amounted to about 70627.04 million pounds, a decrease of about 4657.55 million pounds, or about 6.19% over the total net yield from the current cropping structure.

As for the reduction of water needs for the cropping structure, the second model (the water needs reduction model) achieved the highest reduction of water needs, as its water needs amounted to about 36691.25 million m3, a decrease of about 604.19 million m3, or about 1.62% of the total water needs of the current cropping composition. The amount is about 37295.44 million m3, followed by the third model (the model of maximizing net yield and minimizing water needs together), as the total water needs for it amounted to about 36989.44 million m3, with a decrease of about 306.00 million m3, or about 0.82% of the total water needs for the current crop structure, followed by The first model (net yield maximization model), where the total water needs amounted to about 37003.94 million cubic meters, with a decrease of about 291.50 million cubic meters, or about 0.78% of the total water needs for the current crop structure.

In light of the findings of the study, it recommends the following:

1- Providing advice to the competent authorities to be guided by the third model (the model of maximizing net yield and minimizing water requirements together), which is considered the most appropriate model, as it achieves a more minimizing of water needs than the first model (the model of maximizing net yield), where minimizing water needs is considered the first priority in the crop structure In addition to achieving a net return to the crop structure.

2- The need to pay attention to expanding the cultivation of strategic crops that are necessary for Egyptian food security, by providing a high net return to farmers, which motivates farmers to plant them.

3- The necessity of working to reduce the area of crops that consume a lot of water, by defining their area, by setting policies that impose more taxes and fines on violators, which leads to achieving a low net return for farmers when they are cultivated, which saves quantities of water, used in the cultivation of reclaimed land.

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