The Optimum Allocation For Irrigation Water of Agricultural Crops in Iraq During The Average Period (2017-2020) Using Linear Programming Method

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Abstract

The research aims to study the optimal allocation of irrigation water that is used to irrigate various agricultural crops at the level of Iraq. In order to achieve the research aim, two economic models were formulated according to the Simplex Algorithm. The two models included forty agricultural crops, which were restricted by twenty specific production resources. The estimated results indicated that there is a surplus of the water resource for both the actual crop composition plan and the proposed basic plans for the two estimated models amounting to about 30.943, 35.357 and 31.097 billion cubic meters for each plan, respectively, compared to the quantities of water available for agricultural use. The results of the analysis of the two estimated models indicated to prefer the results of plans with legislative restrictions due to the expansion of the area of strategic and important crops for local consumption, with less needs of water.

Key words: Water balance, Agricultural crops, Optimization, Linear programming models.

1. Introduction

Water resources occupy at the present time the top of the concerns of the countries of the world. The developed countries have paid great attention to those resources in order to develop and preserve them from extravagance and waste, raising the efficiency of their use, maximizing the returns from them, and the use of modern advanced methods to meet the increasing demand for water resources in all uses [1]. The phenomenon of water scarcity is one of the most important challenges facing the world today, as a result of the severe shortage of water imports due to the tendency of most countries in the world in general to increase water storage and legalize its release, and because the development and prosperity of the agricultural sector depends mainly on several elements, the most important of which is irrigation water, its abundance, and the methods of its use in order to provide large quantities of water and raise the productivity rate of agricultural crops, where the water shortage directly threatens this sector [2].

The importance of water resources in general increases as the degree of scarcity of these resources and the extent of the needs for them increases due to the fluctuations in these resources from year to year. As a result, the high uncertainty about the supply of water resources available for use in the country concerned, as it was exposed in recent years to a drought crisis due to the decline of most rivers and seas levels, so it became necessary to rationalize its use in the widespread agricultural area to increase the efficiency of irrigation and reduce water losses [3]. What exacerbates the severity of the water problem in Iraq are the methods of using water resources, the traditional practices of field irrigation operations, and the lack of commitment of farmers to irrigation in the specified and appropriate times and quantities, which has led to the lack of water availability at all times needed by the dominant agricultural crops composition at the present time [4].

The problem of water scarcity is one of the main problems facing the agricultural sector in Iraq, and it is limited to how to rationalize the use of this sector's water in light of the current condition. The levels of the Tigris and Euphrates rivers have decreased in recent years, and on the other hand, the demand for water has increased, in addition to the misuse of water resources and the lack of optimal utilization of them, which negatively affects the return of the water unit [5]. The excessive use of water leads to the absence of an excess of water that allows irrigation of new areas of reclaimed acreage. Therefore, the best alternatives to the current crop composition must be found in light of the objectives of the agricultural policy strategy towards the optimal use of productive resources, especially the water resource, so that these alternatives and options can be
placed in front of the country's decision-makers. In addition, there is a deviation from the crop composition that enables the reduction of water needs and the achievement of the maximum possible profit in light of the set of restrictions and limitations of the available resources.

This research aims to achieve sub-goals focused in their entirety at reaching the best alternatives for optimal allocation of the use of irrigated water in Iraqi agriculture, where these goals are represented by the following:

- Analysis of the Iraqi water balance for the 2019-2020 agricultural seasons.
- Estimating the surplus quantities of irrigated water from the dominant crop composition at the level of Iraq during the average period (2017-2020).
- Determine the optimum crop composition that maximizes the profit margin of a unit of water during the average period (2017-2020).

2. Materials and Methods

2.1 Conceptual framework

The research is based on quantitative mathematical techniques that are widely used similarly in military applications, economic, social, and service studies. It is a linear programming technique, as a planning method that contributes to analyzing and solving the problems of the great and small ends that face productive decision makers who work under the weight of certain restrictions and controls that limit their ability to choose the most appropriate decisions, and then benefit from the final results that are reached in addressing the problems of optimal distribution for scarce productive resources, and the ability to measure, compare and predict in order to evaluate the available alternatives to choose the best of them [6].

Linear programming is known as a scientific mathematical method concerned with addressing the problem of resources allocation or specific energies to achieve a specific goal, and this goal is expressed by a linear function called the goal function, and most often the function is a profit function, a cost function, or a productive energy function, etc. [7]. The term programming means a set of sequential and specific mathematical steps to achieve a specific goal and optimal results by choosing the optimal alternative from among a group of available alternatives, while the term linearity means that the relationship among variables is linked by linear mathematical functions that can be represented by a straight line [8]. The linear programming technique is based on a set of assumptions [9], namely:

- Linearity: To apply linear programming, the relationship in the objective function and in inequalities is assumed to be a linear relationship, meaning that there is a linear relationship between the variables affecting the problem under study, so when any change in the value of one of them causes proportional and constant changes in the value of the other.
- Addition: This means that the quantities of raw materials entered into production and the quantities of production are subject to addition, and it is stipulated that there is no intersection among production activities. In other words, the sum of the outputs of productive activities is the sum of the output of each productive activity separately within a single plan.
- Limitations: This hypothesis means resources and activities are limited, as there is no infinite number of alternative activities and available resources.
- The size of the non-negative activity: This hypothesis means that negative quantities of the volume of activity are not possible. This assumption is one of the basic and necessary assumptions when setting up the inequalities that define the constraints on solving the problem.
- Independence: Choosing any activity does not necessarily require choosing another activity; this indicates the independence of the productive elements.
- Knowledge and certainty: - All values in the linear program model must be known and there are no probability values.

The formulation of linear programming models includes three basic components, which are [10]:

- The objective function: that is, defining the target function, this requires expressing it in a quantitative manner. The function is placed in the form of a mathematical equation to express maximizing profit margin or output, or minimizing costs. The possibility of expressing the target in any problem depends on the type and nature of the problem to be solved using this method. The objective function can be expressed mathematically as follows:

\[
\text{Max } Z = \sum_{j=1}^{n} C_j X_j
\]
Where $Z$ represents the total target function (maximizing or minimizing), $C_j$ represents the profit margin achieved per dunum of the $(j)$ productive activity, and $X_j$ represents the group of agricultural activities included in the plan.

- **Constraints and limitations:** Due to the limited of economic resources, the quantity of each resource is used as a constraint or a limitation in linear programming models. The restrictions mean that they are the various factors that limit the use of any of the alternative activities that can be used to solve the problem, whether it expresses the available amount of the resource or other physical, economic or social restrictions. Constraints are formulated on the basis of the data of the linear programming problem and on the basis of technical production relations, the matrix of resources or constraints can be expressed mathematically as follows:

$$\text{Subject To:}$$

$$\sum_{j=1}^{n} A_{ij} X_j \leq R_i \quad i = 1 \ldots m$$

Where $A_{ij}$ represents the matrix of technical parameters of the set of resources and constraints included in the plan, and it means the requirements or needs of one dunum of $(j)$ agricultural crop of $(i)$ the economic resource, $R_i$ represents the available quantities of the group of resources under study.

- **Non-negative constraint:** Economic variables such as production levels and area quantities, cannot take negative values, and these variables have no economic significance if they take negative values. Therefore, a non-negative constraint is placed to avoid taking the economic variables negative values, so they take positive values or equal to zero:

$$X_j \geq 0$$

### 2.2 Data of study

In order to achieve the objectives of the research in practice, the study relied on secondary data for the average time period (2017-2020) for the following three agricultural seasons:

- Data of the 2017-2018 agricultural seasons (winter - summer).
- Data of the 2018-2019 agricultural seasons (winter - summer).
- Data of the 2019-2020 agricultural seasons (winter - summer).

As these agricultural seasons included a group of vegetables and the dominant crops cultivated at the country level. The basic information and data are the total areas of the study crops during the aforementioned seasons, the variable costs, the total revenues achieved per dunum of each crop, as well as the available quantities of irrigation water at the level of Iraq and the needs of one dunum of different crops per unit of water. These data were obtained from its various local sources, which included the Ministry of Planning, the Ministry of Agriculture and the Ministry of Water Resources [11, 12, and 13], in addition to previous published scientific research and studies related to the research topic.

### 2.3 Study models

The research is based on both the descriptive method (represented by percentages and averages) and the quantitative mathematical method using linear programming technique in analyzing the data and extracting the required results through the use of the statistical program QSB [14] With the same line of previous studies [15], two basic economic models were formulated and analyzed according to a linear programming method, All of them aim to the rational use of limited water resources, as these models take the following mathematical forms:

#### 2.3.1 The linear programming model that maximizes the profit margin of the dominant crop combination during the average period (2017-2020), as this model includes the following plans

The first plan - a linear programming model that maximizes the profit margin of the prevailing crop combination during the average period (2017-2020) without including legislative restrictions, this model consists of:

A- The objective function: This plan includes (40) agricultural crops, and the main goal of this model is to maximize the total profit margin of one dunum from the optimal crop composition as well as to detect the size of the surplus of the irrigation waters.
B- A set of restrictions and limitations; includes:

- Land resource restrictions: include four restrictions, the first of which is for the total arable areas at the level of Iraq, excluding the areas of gardens, palms, and areas of the Kurdistan region, which are not included in the analysis of the model. The second restriction is related to the total area of winter crops, while the third restriction is related to the total area of summer crops. The last one is for the total area of perennial crops.

- Water resources restrictions: assume that the amount of irrigation water for the crops of the model under study does not exceed the total amount of irrigation water available, as (12) water restrictions were formulated representing the total monthly water needs for the crops included in the model, where the amount of available water was calculated per month for agricultural crops.

- Human labor restrictions: assume that the number of work days for the agricultural crops under study does not exceed the total number of work days available, as (4) restrictions for agricultural labor were formulated representing the total seasonal manual labor needs of the agricultural crops included in the model.

The second plan - a linear programming model that maximizes the profit margin of the prevailing crop combination during the average period (2017-2020) with the imposition of legislative restrictions: This model consists of the same components of the first plan with the addition of a set of legislative or regulatory restrictions that represent the areas of the group of crops that farmers must cultivate it, as well as the areas of the group of crops that were recently prevented from import by the Iraqi Ministry of Agriculture (in the event that they did not appear in the results of the first plan). Figure 1 shows the mathematical formulation matrix diagram of the first linear programming model.

![Figure 1. A matrix formulation diagram of the first linear programming model.](image-url)
2.3.2 The linear programming model that maximizes the profit margin of the water unit of the dominant crop combination during the average period (2017-2020), as this model includes the following plans

The first plan - a linear programming model that maximizes the profit margin of the water unit of the prevailing crop combination during the average period (2017-2020) without legislative restrictions, this model consists of:

A- Function of the objective: The main objective of this model is to maximize the total profit margin per cubic meter of irrigation water for the optimal crop composition, as well as to detect the size of the surplus from the irrigation waters, this plan also includes (40) agricultural crops. The profit margin of one cubic meter of irrigation water for each crop was calculated by dividing the profit margin of one dunum (presented in Figure 1) by the amount of irrigation water needs per dunum during the agricultural season.

B- A set of restrictions and limitations; includes:

- Land resource restrictions: include four restrictions, the first of which is for the total arable areas at the level of Iraq, excluding the areas of gardens, palms, and areas of the Kurdistan region, which are not included in the analysis of the model. The second restriction is related to the total area of winter crops, while the third restriction is related to the total area of summer crops. The last one is for the total area of perennial crops.
- Water resources restrictions: assume that the amount of irrigation water for the crops of the model under study does not exceed the total amount of irrigation water available. Where 12 water restrictions were formulated representing the total monthly water needs for the crops included in the model.
- Human labor restrictions: assume that the number of work days for the agricultural crops under study does not exceed the total number of work days available. Where 4 restrictions for agricultural labor were formulated representing the total seasonal manual labor needs of the agricultural crops included in the model.

The second plan - a linear programming model that maximizes the profit margin of the water unit of the dominant crop combination during the average period (2017-2020) by adding legislative restrictions: This model consists of the same components of the first plan with the addition of a set of legislative restrictions that represent the areas of the crops that farmers must cultivate them, as well as the areas of the crops that were recently prevented from import by the Iraqi government (if they did not appear in the results of the first plan). Figure 2 shows the mathematical formulation matrix diagram of the second linear programming model.
3. Results and discussion

3.1 Results of the analysis of the Iraqi water balance

The study of the water balance of any country is important so that it can determine the most important uses of the available water in that country. The water balance consists of two sides, namely: the available water resources side and the uses of those water resources. Table 1 shows the relative importance of the components of the Iraqi water balance for the 2017-2018 Agricultural seasons.

| Water Resources Items | The available amount of water (billion m3/year) | % | Items | The amount of uses (billion m3/year) | % |
|-----------------------|-------------------------------------------------|---|-------|-------------------------------------|---|
| Tigris River and its tributaries except Aleethem | 22.81 | %69 | Agriculture | 30.71 | %86 |
| Aleethem | 0.81 | %2 | Homes | 1.07 | %3 |
| The Euphrates River in Husaybah | 9.58 | %29 | Industry | 1.79 | %5 |
| Total | 33.20 | %100 | environment | 2.14 | %6 |
| Total | 35.71 | %100 | Total | 35.71 | %100 |

Source: organized and calculated by the researchers based on the data obtained from the Ministries of Water Resources and Planning.

Table 1 shows that most of Iraq's water resources come from the Tigris River and its tributaries, as those resources ranked first with a rate of 69%, or nearly three quarters of the total water resources, followed by the Euphrates River resources at a rate of about 29%. As for the aspects of disposal of those water resources, Table 1 shows that most of the water uses are consumed by the agricultural sector in the country at a rate of about 86% of the total water uses at the local level, followed by environmental uses at a rate of about 6%.
3.2 Results of the analysis of the actual crop composition at the level of Iraq during the average period (2017-2020)

Table 2 shows that the dominant crop composition at the level of Iraq during three agricultural seasons (2017-2020) includes forty agricultural crops, and this crop composition has achieved a total profit margin estimated at about 1029.35838 billion Iraqi dinars, with a total average of cultivated areas amounted to about 7554101 dunums during the same period. The water needs for the current crop composition were estimated at 4.737 billion m³. The actual crop composition will be used in finding the proposed solutions using the linear programming method, and the resulting profit margin will be compared with the value of the optimal crop composition that will be produced by the results of the linear programming technique models according to the Simplex algorithm.

| No. | Crops       | Cultivated area / dunums | Total revenue of a dunum / dinar | Total cost of supplies per dunum / dinar | Total profit margin of dunum / dinar | No. | Crops       | Cultivated area / dunums | Total revenue of a dunum / dinar | Total cost of supplies per dunum / dinar | Total profit margin of dunum / dinar |
|-----|-------------|--------------------------|---------------------------------|------------------------------------------|-------------------------------------|-----|-------------|--------------------------|---------------------------------|-----------------------------------|-----------------------------------|
| 1   | Wheat       | 4567000                  | 38421                           | 256938                                   | 12727                               | 21  | Tomatoes    | 74239.666666              | 16599                           | 124450                           | 41499                             |
| 2   | Barley      | 1714000                  | 22800                           | 114004                                   | 11400                               | 22  | Cucumber    | 61388.6                   | 2852                            | 213968                           | 71322                             |
| 3   | Pistachios  | 3377.5                   | 34032                           | 170161                                   | 17016                               | 23  | Green Beans | 9627.5                   | 47994                           | 407952                           | 71991                             |
| 4   | Chickpeas   | 389                      | 37597                           | 225582                                   | 15038                               | 24  | Eggplant     | 29017                   | 4780                            | 406317                           | 71703                             |
| 5   | Lentil      | 19                       | 32547                           | 195282                                   | 13018                               | 25  | Zucchini     | 8363.266666               | 60045                           | 420316                           | 18013                             |
| 6   | Turnip      | 6971.5                   | 34231                           | 273848                                   | 68462                               | 26  | Okra         | 28523.8333               | 70362                           | 457357                           | 24626                             |
| 7   | Beetles     | 2097.333                 | 39295                           | 294719                                   | 98239                               | 27  | Watermelon   | 56511.3333               | 17756                           | 142048                           | 35512                             |
| 8   | Carrots     | 1381.333                 | 31379                           | 251038                                   | 62759                               | 28  | Melon        | 37815.3333               | 381                             | 304880                           | 76220                             |
| 9   | Cauliflower | 4295                     | 41432                           | 310742                                   | 10358                               | 29  | Dry Beans    | 13132                   | 35854                           | 286838                           | 71709                             |
| 10  | Cabbage     | 3430                     | 32225                           | 256691                                   | 85564                               | 30  | Cotton       | 79                     | 19763                           | 98817                            | 98816                             |
| 11  | Spinach     | 2111                     | 51709                           | 387812                                   | 12927                               | 31  | Sesame       | 7872.5                  | 34518                           | 172594                           | 17259                             |
| 12  | Lettuce     | 16802.5                  | 41313                           | 330504                                   | 82626                               | 32  | Sunflower    | 767                    | 52147                           | 365029                           | 15644                             |
| 13  | Green Onion | 23748.33                 | 44132                           | 308927                                   | 13239                               | 33  | Potato       | 44510.666666              | 34341                           | 274728                           | 68682                             |
| 14  | Collard     | 2635.5                   | 48804                           | 414836                                   | 73206                               | 34  | Dry Onion    | 22001.166666              | 44512                           | 311584                           | 13353                             |
| 15  | Radish      | 3910.5                   | 53588                           | 455500                                   | 80382                               | 35  | Yellow Corn  | 229106                  | 40970                           | 398212                           | 11495                             |
| 16  | Beans       | 1714.333                 | 95919                           | 575516                                   | 38367                               | 36  | Sorghum      | 123637                  | 75485                           | 350000                           | 40485                             |
| 17  | Garlic      | 1777.666                | 72304                           | 506132                                   | 21691                               | 37  | Mung bean    | 1374.7                  | 29290                           | 175745                           | 11716                             |
| 18  | Peas        | 128                      | 91923                           | 689425                                   | 22980                               | 38  | Hay          | 11392.666666              | 54989                           | 494903                           | 54989                             |
| 19  | Rice        | 266534                   | 95000                           | 403305                                   | 54669                               | 39  | Clover       | 39687.666666              | 71844                           | 646597                           | 71844                             |
| 20  | Pepper      | 10536.66                | 7209                           | 540728                                   | 18024                               | 40  | Millet Seeds | 7290                   | 71626                           | 573010                           | 14325                             |
Total profit margin for the total cultivated areas at the level of Iraq (Iraqi dinars) = Total (area planted with the crop x dunum profit margin for the crop) = 102935838000
Total profit margin of the water unit for the cultivated areas at the level of Iraq (Iraqi dinars) = total (total profit margin of a dunum ÷ water ration of the crop) = 1704405110.16
Source: organized and calculated by the researchers based on the data obtained from the Ministries of Agriculture and Planning.

3.3 Results of the optimal allocation of water resources in the Iraqi agricultural sector

3.3.1 The linear programming model that maximizes the profit margin of the dominant crop combination during the average period (2017-2020)

3.3.1.1. Results of analyzing the linear programming model that maximizes the profit margin of the prevailing crop combination during the average period (2017-2020) without including legislative restrictions

Table 3 shows the results of the analysis of the linear programming model, which maximizes the total profit margin achieved in light of the proposed areas in the plan, where the total target function amounted to about 3028.773 billion Iraqi dinars, with three agricultural crops:
- Winter crops group: The model suggests an increase in the green bean crop area to about 6.354075 million dunums.
- Summer crops group: The model suggests an increase in the areas of rice crop to about 770,876 thousand dunums.
- Fodder crops group: The model suggests expanding the areas planted with millet to about 153,612 thousand dunums.

The results in Table 3 show that there is a large surplus of restrictions and economic resources included in the simplex table (water, employment), especially the water resource, where the total surplus quantities of irrigation water amounted to about 31 billion m3 out of a total of 35.679 billion m3 available for agricultural use during the average period (2017-2020), distributed over the different months of the year.

Table 5 shows the results of the comparison between the economic indicators of the actual crop combination during the average period (2017-2020) and the results of the proposed solution for the first linear programming model without introducing legislative restrictions, where the difference between the actual and proposed profit margin per dunum amounted to about 265 thousand Iraqi dinars, with an increase of about 194% compared to the current crop composition, the amount of irrigation water required for the actual composition was about 4.737 billion m3, while the amount of irrigation water needed for the optimal composition was about 4.497 billion m3, with a difference of about 240 million m3, a decrease of about 5% compared to the current crop composition. Regarding the volume of labor used, it was estimated at about 234.172 million working hours for the current composition, while it was estimated at about 544,307 million working hours for the optimal combination, with an increase of about 132% compared to the actual crop combination during the average period (2017-2020).

Table 3. Results of the simplex table analysis of the first linear programming model without including legislative restrictions.

| No. | Decision Variable | Solution Value | Unit Profit c(j) | Total Contribution | Constrai nt | Left Hand Side | Right Hand Side | Slack or Surplus |
|-----|------------------|----------------|-----------------|-------------------|-------------|----------------|----------------|-----------------|
| X1  | Wheat            | 0              | 127,278.00      | 0                 | Total area  | 7554101.0      | 7,554,101.000   | 0               |
|     |                  |                | 00              | 0                 | Winter area | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Summer area | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X2  | Barley           | 0              | 114,004.00      | 0                 | Total area  | 160902.0      | 160,902.00000 | 0               |
|     |                  |                | 00              | 0                 | Winter area | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Summer area | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X3  | Pistachios       | 0              | 170,161.00      | 0                 | Total area  | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Winter area | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Summer area | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X4  | Chickpeas        | 0              | 150,388.00      | 0                 | Total area  | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Winter area | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Summer area | 160902.0      | 160,902.00000 | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X5  | Lentil           | 0              | 130,188.00      | 0                 | Total area  | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Winter area | 160902.0      | 160,902.00000 | 0               |
|     |                  |                | 00              | 0                 | Summer area | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X6  | Turnip           | 0              | 68,462.000      | 0                 | Total area  | 160902.0      | 160,902.00000 | 0               |
|     |                  |                | 00              | 0                 | Winter area | 1037410.0      | 1,037,410.000   | 0               |
|     |                  |                | 00              | 0                 | Summer area | 6355789.0      | 6,355,789.000   | 0               |
|     |                  |                | 00              | 0                 | Perennial area | 160902.0 | 160,902.00000 | 0               |
| X7 | Beetle      | 0 | 98,239,000 | 0 | 0 | Water | 499799500 | 2,598,584,000.0 | 2098784500 |
| X8 | Carrots     | 0 | 62,759,000 | 0 | 0 | Water | 499799500 | 2,428,877,000.0 | 1929077500 |
| X9 | Cauliflower | 0 | 103,580,000 | 0 | 0 | Water | 863100500 | 2,911,956,000.0 | 2048855500 |
| X1 | Cabbage     | 0 | 85,564,000 | 0 | 0 | Water | 370844600 | 2,987,539,000.0 | 2442546400 |
| X1 | Spinach     | 0 | 129,273,000 | 0 | 0 | Water | 370844600 | 2,813,391,000.0 | 2426147500 |
| X1 | Lettuce     | 0 | 82,626,000 | 0 | 0 | Water | 863100500 | 3,289,248,000.0 | 2426147500 |
| X1 | Green Onion | 0 | 132,397,000 | 0 | 0 | Water | 492255800 | 3,622,268,000.0 | 3270067000 |
| X1 | Collard Green | 0 | 71,991,000 | 0 | 0 | Water | 386x799500 | 3,207,116,000.0 | 3207116000 |

Objective Function (Max.) = 3,028,772,805,196
3.3.1.2 Results of the analysis of the linear programming model that maximizes the profit margin of the dominant crop combination during the average period (2017-2020) with adding legislative restrictions

As an attempt to improve the results of resolving the previous model, a set of legislative or regulatory restrictions related to the allocation of certain agricultural areas to some field and vegetable crops that did not appear in the first plan has been included and added, as follows:

- Area of wheat (X1) = 4567000 dunums
- Area of barley (X2) = 1714000 dunums
- Area of yellow corn (X35) = 229106 dunums
- Area of tomatoes (X21) = 74240 dunums
- Area of eggplant (X24) = 29017 dunums
- Area of cabbage (X10) = 3430 dunums
- Area of cauliflower (X9) = 4295 dunums
- Area of potato (X33) = 44511 dunums
- Area of carrots (X8) = 1382 dunums
- Area of lettuce (X12) = 16803 dunums
- Area of garlic (X17) = 1778 dunums
- Area of zucchini (X25) = 8364 dunums
- Area of pepper (X20) = 10537 dunums
- Area of turnip (X6) = 6972 dunums
- Area of beetles (X7) = 2098 dunums
- Area of green onions = 23749 dunums
- Area of cucumber = 61388 dunums

Table 4 shows the results of the analysis of the linear programming model that maximizes the gross profit margin achieved with the presence of legislative restrictions in light of the proposed areas in the plan. The cultivation of basic and required crops and vegetables has been expanded, and the total target function amounted to about 1147.496 billion Iraqi dinars, with twenty agricultural crops:

- Winter crops group: It includes wheat (X1), barley (X2), turnip (X6), beetle (X7), carrots (X8), cauliflower (X9), cabbage (X10), lettuce (X12), green onions (X13), green beans (X16) and garlic (X17).
- Summer crops group: It includes rice (X19), peppers (X20), tomatoes (X21), cucumbers (X22), eggplants (X24), zucchini (X25), potatoes (X33) and maize (X35).
- Fodder crops group: It includes only millet crop (X40).

The total exploited summer areas amounted to about 1037410 dunums, with annual water needs estimated at about 1.277 billion m³, while the total exploited winter areas amounted to about 6,355,789 dunums, with total water needs estimated at about 3.363 billion m³ annually. Despite the economic excellence of the results presented in Table 4, the estimated model suggests an increase in the areas allocated to green beans, rice and millet crops by 735%, 118%, and 2107% compared to those crops actually grown during the average period (2017-2020), respectively.

Table 5 shows the results of the comparison between the economic indicators of the actual crop combination during the average period (2017-2020) and the results of the proposed solution for the first linear programming model with adding legislative restrictions, where the difference between the actual and proposed profit margin of a dunum amounted to about...
15,639 Iraqi dinars, with an increase of about 11.5% compared to the current cropping combination. The amount of irrigation water required for the actual combination amounted to about 4,737 billion m³, while the amount of irrigation water needed for the optimal combination amounted to about 4,730 billion m³, with a difference of about 7 million m³, a decrease of about 0.15% compared to the current cropping combination.

With regard to the volume of labor used, it was estimated at about 234.172 million working hours for the current combination, while it was estimated at about 180.125 million working hours for the optimal combination, with a decrease of about 23.1% compared to the prevailing crop composition during the average period (2017-2020).

**Table 4.** Results of the simplex table analysis of the first linear programming model with the imposition of legislative restrictions.

| No. | Decision Variable | Solution Value | Unit Profit c(j) | Total Contribution | Constraint | Left Hand Side | Right Hand Side | Slack or Surplus |
|-----|-------------------|----------------|------------------|-------------------|------------|----------------|----------------|-----------------|
| X1  | Wheat             | 4567000.00     | 0                | 127278.00         | Total area | 7554101.00    | 7,554,101.0000 | 0               |
| X2  | Barley            | 1714000.00     | 0                | 114004.00         | Winter area | 6355789.00    | 6,355,789.0000 | 0               |
| X3  | Pistachios        | 0              | 0                | 170161.00         | Summer area | 1037410.00    | 1,037,410.0000 | 0               |
| X4  | Chickpeas         | 0              | 0                | 150388.00         | Perennial area | 160902.00  | 160,902.0000   | 0               |
| X5  | Lentil            | 0              | 0                | 130188.00         | Water Jan. | 558083700.00  | 5,580,837.0000 | 0               |
| X6  | Turnip            | 6971.00        | 0                | 68462.00          | Water Feb. | 560411600.00  | 5,604,116.0000 | 0               |
| X7  | Beetles           | 2097.00        | 0                | 98239.00          | Water Mar. | 645170400.00  | 6,451,704.0000 | 0               |
| X8  | Carrots           | 1381.00        | 0                | 62759.00          | Water Apr. | 645170400.00  | 6,451,704.0000 | 0               |
| X9  | Cauliflower       | 4295.00        | 0                | 103580.00         | Water May | 279974700.00  | 2,799,747.0000 | 0               |
| X1  | Cabbage           | 3430.00        | 0                | 85564.00          | Water Jun. | 275170400.00  | 2,751,704.0000 | 0               |
| X1  | Spinach           | 0              | 0                | 129273.00         | Water Jul | 226912000.00  | 2,269,120.0000 | 0               |
| X1  | Lettuce           | 16802.00       | 0                | 82626.00          | Water Aug. | 280297400.00  | 2,802,974.0000 | 0               |
| X1  | Green Onion       | 23748.00       | 0                | 132397.00         | Water Sep. | 79577550.00   | 795,775.5000   | 0               |
| X1  | Collard Green     | 0              | 0                | 73206.00          | Water Oct. | 10197130.00   | 1,019,713.00   | 0               |
| X1  | Radish            | 0              | 0                | 80382.00          | Water Nov. | 572988600.00  | 5,729,886.00   | 0               |
| X1  | Beans             | 14288.10       | 0                | 383678.00         | Water Dec. | 561973000.00  | 5,619,730.00   | 0               |
| X1  | Garlic            | 1777.00        | 0                | 216914.00         | Labor 1    | 44561650.00   | 4,456,165.00   | 0               |
| X1  | Peas              | 0              | 0                | 229808.00         | Labor 2    | 37696090.00   | 3,769,609.00   | 0               |
| X1  | Rice              | 580251.00      | 0                | 546695.00         | Labor 3    | 29767410.00   | 2,976,741.00   | 0               |
| X2  | Pepper            | 10536.00       | 0                | 180242.00         | Labor 4    | 6810160.00    | 681,016.00     | 0               |
| X2  | Tomatoes          | 74239.00       | 0                | 41499.00          | 0          | 308084426.00  | 30,808,442.60  | 0               |
| X2  | Cucumber          | 61388.00       | 0                | 71322.00          | 0          | 437831493.60  | 43,783,149.36  | 0               |
| X2  | Green             | 0              | 0                | 71991.00          | 0          | 0             | 0              | 0               |
| Model Indicators | Plan of actual crop composition | Results of optimal first plan | Results of optimal second plan |
|------------------|--------------------------------|-------------------------------|-------------------------------|
| Number of proposed crops | 40 | 3 | 20 |
| Total cultivated area / dunum | 7554101 | 7554101 | 7554101 |
| Total profit margin / billion Iraqi dinars | 1029 | 3028 | 1147 |
| Profit margin of dunum / Iraqi dinars | 136265 | 400944 | 151904 |
| Average annual water requirement / billion m3 | 4.736726 | 4.497263 | 4.730305 |
| Surplus quantities of water / billion m3 | 30.943 | 35.357 | 31.097 |
| Average annual labor requirement / million hours | 234.171580 | 544.306855 | 180.125295 |

Source: organized and calculated by the researchers based on the results of the study data analysis
3.3.2 The linear programming model that maximizes the profit margin of the water unit of the dominant crop combination during the average period (2017-2020)

3.3.2.1 Results of the analysis of the linear programming model that maximizes the profit margin of the water unit of the prevailing crop combination during the average period (2017-2020) without legislative restrictions:

This model aims to develop an alternative plan for the crop composition in order to maximize the profit margin of a cubic meter of the water resource (profit margin of a dunum ÷ the amount of irrigation water needed for a dunum). Table 6 shows the results of the analysis of the linear programming model that maximizes the total profit margin of the water unit in light of the proposed areas in the plan, where The total target function amounted to about 5.693 billion Iraqi dinars, with three agricultural crops: green beans, rice and millet. It is also evident from Table 6 that there is a large surplus of the water distributed over the different months of the year. Generally, this model suggests the expansion of the areas of crops shown in the plan in a way that does not fit with the actual demand for them.

Table 8 shows the results of the comparison between the economic indicators of the actual crop composition during the average period (2017-2020) and the results of the proposed solution for the second linear programming model without introducing legislative restrictions, where the difference between the actual and proposed profit margin of the water unit per dunum was about 528 Iraqi dinars, with an increase of about 234% compared to the current crop composition, The amount of irrigation water required for the actual composition was about 4.737 billion m3, while the amount of irrigation water needed for the optimal composition was about 4.497 billion m3, with a difference of about 240 million m3, a decrease of about 5% compared to the current crop composition. Regarding the volume of labor used, it was estimated at about 234.172 million working hours for the current composition, while it was estimated at about 544.307 million working hours for the optimal combination, with an increase of about 132% compared to the actual crop combination during the average period (2017-2020). Generally this model is also illogical and cannot be recommended to apply due to the absence of most of the strategic agricultural crops and necessary crops for local consumption. Of course, the results of this model give clear indications of the higher crop, a profit margin for the unit of water, and this is not necessarily a possible activity in the light of the technical and economic constraints that accompany the optimal utilization of the available resources.

Table 6. Results of the simplex table analysis of the second linear programming model without including legislative restrictions.

| No. | Decision Variable | Solution Value | Unit Profit c(\text{j}) | Total Contribution | Constraint | Left Hand Side | Right Hand Side | Slack or Surplus |
|-----|-------------------|----------------|-------------------------|--------------------|------------|---------------|----------------|-----------------|
| X1  | Wheat             | 0              | 226.231                 | 0                  | Total area | 7554101.00    | 7,554,101.0000 | 0               |
| X2  | Barley            | 0              | 260.759                 | 0                  | Winter area| 6355789.00    | 6,355,789.0000 | 0               |
| X3  | Pistachios        | 0              | 125.580                 | 0                  | Summer area| 1037410.00    | 1,037,410.0000 | 0               |
| X4  | Chickpeas         | 0              | 553.303                 | 0                  | Perennial area | 160902.00    | 160,902.0000  | 0               |
| X5  | Lentil            | 0              | 478.984                 | 0                  | Water Jan. | 0             | 2,502,835.0000 | 2502835000.00 |
| X6  | Turnip            | 0              | 121.537                 | 0                  | Water Feb. | 0             | 2,630,189.0000 | 2630189000.00 |
| X7  | Beetles           | 0              | 181.873                 | 0                  | Water  | 0             | 0               | 0               |
| X8  | Carrots           | 0              | 135.052                 | 0                  | Water Mar. | 0             | 0               | 0               |
| X9  | Cauliflower       | 0              | 200.348                 | 0                  | Water Apr. | 0             | 2,428,877.0000 | 1929077500.00 |
| X1  | Cabbage           | 0              | 140.360                 | 0                  | Water May | 0             | 2,911,956.0000 | 2048855500.00 |
| X1  | Spinach           | 0              | 239.328                 | 0                  | Water Jul. | 0             | 2,813,391.0000 | 2442546400.00 |
| X1 | Lettuce | 0 | 177,805 | 0 | 0 | Water Aug. | 863100500.00 | 0 | 0 | 3,289,248,000.00 | 0 | 0 | 2426147500.00 | 0 |
| X1 | Green | 0 | 168,830 | 0 | 0 | Water Sep. | 499799500.00 | 0 | 0 | 3,622,268,000.00 | 0 | 0 | 3122468500.00 | 0 |
| X1 | Collard Green | 0 | 135,529 | 0 | 0 | Water Oct. | 492255800.00 | 0 | 0 | 3,530,667,000.00 | 0 | 0 | 3038412000.00 | 0 |
| X1 | Radish | 0 | 172,976 | 0 | 0 | Water Nov. | 3,270,067,000.00 | 0 | 0 | 0 | 0 | 3270067000.00 | 0 |
| X1 | Beans | 6355789.0 | 825,646 | 0 | 0 | Water Dec. | 3,207,116,000.00 | 0 | 0 | 0 | 0 | 3207116000.00 | 0 |
| X1 | Garlic | 0 | 276,605 | 0 | 0 | Labor 1 | 114040000.00 | 0 | 1,334,604,000.00 | - | - | 112705396.0 | 0 |
| X1 | Peas | 0 | 671,756 | 0 | 0 | Labor 2 | 167647100.00 | 0 | 1,317,218.0000 | - | - | 166329882.0 | 0 |
| X1 | Rice | 1037410.0 | 390,273 | 0 | 0 | Labor 3 | 0 | 1,302,901.0000 | - | - | 1302901.00 | 0 |
| X2 | Pepper | 0 | 199,294 | 0 | 0 | Labor 4 | 262619800.00 | 0 | 1,302,901.0000 | - | - | 261316899.0 | 0 |
| X2 | Tomatoes | 0 | 49,0398 | 0 | 0 | 0 | 0 |
| X2 | Cucumber | 0 | 97,5944 | 0 | 0 | 0 | 0 |
| X2 | Green Beans | 0 | 210,438 | 0 | 0 | 0 | 0 |
| X2 | Eggplant | 0 | 123,158 | 0 | 0 | 0 | 0 |
| X2 | Zucchini | 0 | 295,497 | 0 | 0 | 0 | 0 |
| X2 | Okra | 0 | 169,047 | 0 | 0 | 0 | 0 |
| X2 | Watermelon | 0 | 44,9291 | 0 | 0 | 0 | 0 |
| X2 | Melon | 0 | 96,4322 | 0 | 0 | 0 | 0 |
| X2 | Dry Beans | 0 | 263,830 | 0 | 0 | 0 | 0 |
| X2 | Cotton | 0 | 75,4782 | 0 | 0 | 0 | 0 |
| X2 | Sesame | 0 | 260,399 | 0 | 0 | 0 | 0 |
| X2 | Sun Flower | 0 | 177,129 | 0 | 0 | 0 | 0 |
| X2 | Potato | 0 | 102,449 | 0 | 0 | 0 | 0 |
| X2 | Dry Onion | 0 | 170,283 | 0 | 0 | 0 | 0 |
| X2 | Yellow Corn | 0 | 8,9372 | 0 | 0 | 0 | 0 |
| X2 | Sorghum | 0 | 388.607 | 0 | 0 | 0 | 0 |
| X2 | Mung bean | 0 | 143,723 | 0 | 0 | 0 | 0 |
| X2 | Hay | 0 | 28,9416 | 0 | 0 | 0 | 0 |

Objective Function (Max.) = 5,693,479,413
3.3.2.2 Results of the analysis of the linear programming model that maximizes the profit margin of the water unit of the dominant crop combination during the average period (2017-2020) with adding legislative restrictions

In this model, a set of restrictions were imposed for areas of food security crops and vegetable crops that were recently banned from import by the Iraqi government and which did not appear in the optimal solution table for the second model (Table 6), where the number of these crops reached seventeen limits or restrictions. Table 7 shows the results of the analysis of the linear programming model that maximizes the total profit margin of the water unit with the presence of legislative restrictions and in light of the areas proposed in the plan.

The cultivation of crops that require low water rations and important for local consumption, such as wheat, barley, cauliflower, garlic and beetles, were included, as well as some vegetable crops with very low elastic demand such as tomatoes, cucumbers, peppers, eggplant, zucchini, potatoes, carrots and lettuce. This resulted in a decrease in the value of the revenue of the crop composition per unit of water compared to the return on the composition of the previous plan, where the total target function amounted to about 1.794 billion Iraqi dinars, with twenty agricultural crops:

- Winter crops group: It includes wheat (X1), barley (X2), turnip (X6), beetles (X7), carrots (X8), cauliflower (X9), cabbage (X10), lettuce (X12), green onions (X13), green beans (X16) and garlic (X17).
- Summer crops group: It includes rice (X19), peppers (X20), tomatoes (X21), cucumbers (X22), eggplants (X24), zucchini (X25), potatoes (X33) and maize (X35).
- Fodder crops group: It includes only millet crop (X40).

The total exploited summer areas amounted to about 1037410 dunums, with annual water needs estimated at about 1.277 billion m³, while the total exploited winter areas amounted to about 6,355,789 dunums, with total water needs estimated at about 3.363 billion m³ annually. In spite of the logical results obtained in this model, the estimated model suggests an increase in the areas allocated to green beans, rice and millet crops than their actually cultivated counterparts during the average period (2017-2020), exceeding the actual demand for them.

It is noted that this plan has achieved a profit margin for the unit of water per dunum that exceeds what is achieved according to the current cropping combination by 5% (reference to Table 8), where the difference between the profit margin for a cubic meter of water for the actual combination and the proposed combination amounted to about 11.4 Iraqi dinars.

The amount of irrigation water required for the actual combination amounted to about 4,737 billion m³, while the amount of irrigation water needed for the optimal combination amounted to about 4,730 billion m³, with a difference of about 7 million m³, a decrease of about 0.15% compared to the current cropping combination.

With regard to the volume of labor used, it was estimated at about 234.172 million working hours for the current combination, while it was estimated at about 180.125 million working hours for the optimal combination, with a decrease of about 23.1% compared to the prevailing crop composition during the average period (2017-2020), and thus this model contributed in solving the problem of unemployment in the agricultural sector, by utilizing all available hours for human labor.

Table 7. Results of the simplex table analysis of the second linear programming model with the imposition of legislative restrictions.

| No. | Decision Variable | Solution Value | Unit Profit c(j) | Total Contribution | Constraint | Left Hand Side | Right Hand Side | Slack or Surplus |
|-----|-------------------|----------------|------------------|--------------------|------------|----------------|----------------|-----------------|
| X1  | Wheat             | 4567000.0      | 226.231          | 103320630.6        | Total area | 7554101.00     | 7,554,101.0000 | 0               |
| X2  | Barley            | 1714000.0      | 260.759          | 46491611.60        | Winter area| 6355789.00     | 6,355,789.0000 | 0               |
| X3  | Pistachios        | 0              | 125.580          | 0                  | Summer area| 1037410.00     | 1,037,410.0000 | 0               |
| X4  | Chickpeas         | 0              | 553.303          | 0                  | Perennial area| 160902.00   | 160,902.0000   | 0               |
| X5  | Lentil            | 0              | 478.984          | 0                  | Water Jan. | 558083700.00  | 2,502,835.0000 | 1944751300.00 |
| X6  | Turnip            | 6971.00        | 121.537          | 847237.22          | Water Feb. | 560411600.00  | 2,630,189.0000 | 2069777400.00 |

Source: organized by the researchers based on the results obtained using the statistical program WIN QSB
| X7  | Beetle   | 2097.00 | 181.873  | 381388.94  | Water    | 645170400.00 | 2,598,584,000.00 | 1953413600.00 |
| X8  | Carrots  | 1381.00 | 135.052  | 186507.78  | Mar.     | 0            | 0                 | 0            |
| X9  | Cauliflower | 4295.00 | 200.348  | 860495.52  | Apr.     | 645170400.00 | 2,428,877,000.00 | 1783706600.00 |
| X1  | Cabbage  | 3430.00 | 140.360  | 481437.89  | Water     | 279974700.00 | 2,911,956,000.00 | 2631981300.00 |
| X1  | Spinach  | 0       | 239.328  | 0          | May Water | 275170400.00 | 2,987,539,000.00 | 2712368600.00 |
| X1  | Lettuce  | 16802.00| 177.805  | 296479.61  | Water     | 280279400.00 | 3,289,248,000.00 | 3008968600.00 |
| X1  | Green    | 23748.00| 168.830  | 409939.146 | Aug.      | 0            | 0                 | 0            |
| X1  | Collard  | 0       | 135.529  | 0          | Sep.      | 79577550.00  | 3,622,268,000.00 | 3542690450.00 |
| X1  | Green    | 0       | 172.976  | 0          | Oct.      | 10197130.00  | 3,530,667,000.00 | 3520469870.00 |
| X1  | Radish   | 14288.10| 825.646  | 11796922.61| Nov.      | 572988600.00 | 3,270,067,000.00 | 2697084400.00 |
| X1  | Beans    | 1777.00 | 276.605  | 491527.97  | Dec.      | 56193100.00  | 3,207,116,000.00 | 2645142900.00 |
| X1  | Garlic   | 0       | 617.756  | 0          | Labor 1   | 44561630.00  | 1,334,604,000.00 | 4322702600.00 |
| X1  | Peas     | 0       | 22456530.62 | 0     | Labor 2   | 37690690.00  | 1,317,218,000.00 | 3637882700.00 |
| X1  | Rice     | 580251.00| 390.273  | 22645630.62| Labor 3   | 29764710.00  | 1,302,901,000.00 | 2846450900.00 |
| X2  | Pepper   | 10536.00| 199.294  | 2099767.91 | Labor 4   | 68100160.00  | 1,302,901,000.00 | 6679725900.00 |
| X2  | Tomatoes | 74239.00| 49.0300  | 3639938.17 | 0         | 0               | 0                 | 0            |
| X2  | Cucumber | 61388.00| 97.5944  | 5991125.03 | 0         | 0               | 0                 | 0            |
| X2  | Green    | 0       | 210.438  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Beans    | 29017.00| 123.158  | 3573696.00 | 0         | 0               | 0                 | 0            |
| X2  | Eggplant | 8363.00 | 295.497  | 2471241.41 | 0         | 0               | 0                 | 0            |
| X2  | Zucchini | 0       | 169.047  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Okra     | 0       | 44.9291  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Watermelon| 0      | 96.4322  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Melon    | 0       | 263.830  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Dry Beans| 0       | 75.4782  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Cotton   | 0       | 260.399  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Sesame   | 0       | 177.129  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Sunflower| 0       | 102.449  | 4560018.34 | 0         | 0               | 0                 | 0            |
| X2  | Potato   | 0       | 170.283  | 0          | 0         | 0               | 0                 | 0            |
| X2  | Yellow   | 229106.00| 8.9372   | 2047566.14 | 0         | 0               | 0                 | 0            |

Objective Function (Max.) = 1,793,994,161
Table 8. Comparison between the results of the actual plan and the plans of second linear programming model in the case of maximizing the profit margin of the water unit.

| Model Indicators                           | Plan of actual crop composition | Results of optimum crop composition without legislative restrictions | Results of optimum crop composition with legislative limitations |
|-------------------------------------------|---------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------|
| Number of proposed crops                  | 40                              | 3                                                                   | 20                                                              |
| Total cultivated area / dunum             | 7554101                         | 7554101                                                             | 7554101                                                         |
| Total profit margin of the water unit / million Iraqi dinars | 1.704405                       | 5.693479                                                            | 1.793994                                                       |
| Profit margin for one dunum of water unit/ dinar-m³ | 226                            | 754                                                                | 237.4                                                          |
| Average annual water requirement / billion m³ | 4.736726                       | 4.497263                                                            | 4.730305                                                       |
| Average annual labor requirement / million hours | 234.171580                    | 544.306855                                                          | 180.125295                                                      |

Source: organized and calculated by the researchers based on the results of the study data analysis

Conclusions

From the results of the research, it can be concluded that the best logical scenarios for the results of the proposed linear programming models, which can be used by economic decision-makers in the country in the future in the case of optimal use of water as an alternative to the current plan scenario, are:

- In a case of maximizing the total profit margin of a dunum during the average period (2017-2020), the model with legislative restrictions can be selected due to the expansion in the area of strategic and important agricultural crops for domestic consumption, with a high profit margin estimated at about 152 thousand Iraqi dinars per dunum, with an increase amounted to about 11.5% compared to the current crop composition. This plan also needs low water quantities, where the amount of irrigation water required for the actual composition amounted to about 4.737 billion m³, while the amount of irrigation water required for the optimal composition was about 4.730 billion m³, with a decrease of about 0.15% compared to the actual crop composition, where the total surplus quantities of irrigated water amounted to about 31 billion cubic meters distributed over the various months of the year, which can be used in other agricultural or non-agricultural fields. In addition, this model contributes to solving the problem of unemployment in the agricultural sector by accommodating all working hours available to the agricultural workforce at the country level without any surplus.

- In the event that the goal is to maximize the profit margin of one cubic meter of water during the average period (2017-2020), the model with regulatory restrictions can also be chosen due to the expansion of the cultivation of strategic agricultural crops that are important to local demand, with a high profit margin for the unit of water exceeds its counterpart achieved according to the actual crop composition. This plan also needs low water quantities with a decrease of about 0.15% compared to the actual composition. In addition this model contributes to solve the problem of unemployment in the agricultural sector by absorbing all the working hours available to the agricultural workforce at the country level.
References

[1] Dief Abd-Almonem, and Abdulrahman Gad. (2016). The Optimal Use of Water Resources of the Egyptian Agriculture in the Current Situation. Mansoura Journal of Agricultural Economics and Social Sciences, 7(6), 643-651
[2] Hamza Yasir. (2015). An Analytical Study of Using Agricultural Water Drainage in Cultivating Field Crops in Damietta Governorate. Mansoura Journal of Agricultural Economics and Social Sciences, 6 (11), 1911-1924
[3] Mahmoud Hassan, and Mohamed Ossama. (2016). An Economic Study for Some Irrigation Systems in Egypt "A case Study of Aswan Governorate", Mansoura Journal of Agricultural Economics and Social Sciences, 7(11), 1047-1057
[4] Harfoush Saad, and Jumaah Mohammed. (2020). Using Different Measurement Methods to Estimate Water Consumption with Some Water Standards, Growth and Yield of Strawberries under Surface Drip- Irrigation. International Journal of Agricultural and Statistical Sciences, 16 (supplement 1), 1495-1500
[5] Abdullah sajad, Abdullah Abdul Hussein, and Ankush Mojitaba. (2019). Assessment of Water Quality in the Euphrates River, Southern Iraq, The Iraqi Journal of Agricultural Sciences, 50 (1): 312 – 319
[6] Alneemey A., Al-Hmdany R., and Al-Hamdany A. (1999). Operation research. 1st edn. Dar Whaal, Printing– Publishing, Amman, p. 125 – 155
[7] Abu Alees Th. (2005). Operation research, Linear Programming. 1st edn. Publications of Omer Almoktar University, Libya, Albedaa. Domestic Bookshop, Bangazy, p. 531 – 682
[8] Luenberger D. (2015). Linear and Nonlinear Programming. 4th ed. Library of Congress Control, Stanford, CA, USA, pp 555
[9] Vanderbei R. (2014). Linear Programming: Foundations and Extensions. 4th ed. International Series in Operations Research & Management Science, Stanford University, CA, USA, Volume 196: pp 420
[10] Singh Jasvinder, and Banerjie Jharna. (2020). Optimum Farming Plans for Marginal Farmers with Restriction on Livestock Enterprises Using Linear Programming Problem. International Journal of Agricultural and Statistical Sciences, 16 (2), 719-731
[11] Ministry of Agriculture, Department of Planning and Follow-up, Statistics Division. Reports of Cultivated Areas in Iraq for the period (2017-2020).
[12] Ministry of Planning and Development Cooperation, the Central Organization for Statistics and Information Technology, Department of Agricultural Statistics. (2021). Database of Agricultural Statistics, Reports of the workforce in Iraq.
[13] Ministry of Water Resources, Department of Planning and Follow-up. (2021). publications and reports of Water Resources in Iraq for the period (2017-2020).
[14] Altaak K., Aalautaby M., and Alashary O. (2009). Quantitative System Applications and Analytics for WIN QSB business. 1st edn. Althakirha Library Publishing, Iraq. pp: 220
[15] Gong Xinghui, Zhang Hongbo, Ren Chongfeng, Sun Dongyong, and Yang Jiantao. (2020). Optimization allocation of irrigation water resources based on crop water requirement under considering effective precipitation and uncertainty. Journal of Agricultural Water Management, 239: 1-10 https://doi.org/10.1016/j.agwat.2019.105708.