Optimal resource allocation to maximize watermelon farmers profits in Rabia subdistrict for the 2024 agricultural season

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Abstract

Watermelon is a plant crop rich in water, which constitutes 92% of its content, making it ideal for hydrating the body in the summer. It also contains many vitamins and minerals. It is grown in more than 100 countries. Watermelon is not just a fruit; it is an integral part of Iraqi food culture and a symbol of special occasions and the summer table. The study aimed to identify the optimal resource combinations used by watermelon farmers in Rabia District for the 2024 agricultural season. The Cobb-Douglas production function was calculated to determine the optimal quantities of resources that maximize profit and minimize cost, and compared to the actual situation. Multiple resource combinations and different production levels were also calculated using isoquant curves, using data collected by a questionnaire for (34) farms, representing 25% of the study population, with an average area of (6) dunums. One of the most prominent results is that the optimal production reached (37,762) kg. The farmers' profits were (5,704,102) dinars. When compared to the actual farmers' production of (29,040) kg, the profits amounted to (2,869,452) dinars. Meanwhile, Profits, including cost reductions, amounted to (4,224,380) dinars. Based on the presented results, the study recommends that watermelon farmers be guided by optimal supply quantities, whether those that maximize profit or minimize cost, to maximize their profits.

Keywords: Production, maximization, minimization, profit, combination.

Introduction

Watermelon (*Citrullus lanatus*) is one of the important summer vegetable crops in Iraq in terms of consumption and ranks first in area and production in the summer, in addition to tomatoes. It is eaten as a refreshing food in the summer and is also used in the manufacture of jams. Every (100) grams of fruit flesh contains (92%) water, (1) gram of protein, (1) gram of various fats, (5) grams of carbohydrates, a small percentage of vitamins (A and B), and a little vitamin (C) [1]. This crop belongs to the Cucurbitaceae family and is grown in countries with a hot and dry climate [2]. Watermelon is grown in the central regions, including Samarra, Baghdad, Diyala, and the northern regions of Iraq, such as Nineveh Governorate, at the beginning of spring, from mid-March until mid-May for local varieties. As for hybrid varieties, they are planted at the end of June and the beginning of July. The global productivity of the dunum ranged between (8-11) tons, as China is the first in the world in its production at a rate of (79) million tons annually, contributing (71%) of the world production, then Turkey comes in second place at a rate of (2.3) million tons annually, contributing (4%) of the world production, In contrast in the Arab world, Algeria comes in first place, followed by Egypt.

In comparison, Iraq occupies the sixth place in the Arab world in the production of dates at 420 thousand tons annually [3]. The cultivation of this crop does not keep pace with the demand for it due to the low productivity of the dunum as well as the limited area exploited for its cultivation despite the presence of vast areas, therefore it is necessary to increase the dunum yield in terms of vertical expansion in its cultivation by using modern methods and improving fertilization, irrigation and insect control methods as well as horizontal expansion of the cultivation of this crop [4]. The areas planted with the watermelon crop in Iraq in (2023) were about (91,500) dunums, and production was estimated at (394,130) tons and a productivity rate per dunum of (4,316) kg, while in Nineveh Governorate the cultivated area for (2023) was (2,016) dunums, with a production rate of (9,260) dunums, and the productivity of one dunum reached (4,593) kg [5].

The problem lies in the fact that the produced watermelon crop can cover only a portion of the market's needs in Nineveh Governorate, meaning that these quantities do not bring the market to self-sufficiency. Furthermore, some farmers lack awareness about adopting the crop, or those who grow it are moving away from it and turning to other crops that are less expensive and, according to their belief, more profitable. Furthermore, those who grow the crop are somewhat detached from using the optimal supply quantities that reduce costs and maximize profits. The lack of input support raises their prices in the markets, resulting in reduced profits for farmers.

Previous studies serve as a guide for subsequent studies, and therefore, it is necessary to present some of the studies and the results they have reached. A study [6] was conducted on the optimal combinations for citrus production in Salah al-Din Governorate. The Cobb-Douglas function was used to estimate the production function to determine the returns to productive capacity and the elasticity of total output resulting from labor and capital. The relationship between inputs and outputs was also analyzed by determining costs of production to calculate the optimal combinations that achieve the highest level of production at the lowest possible cost. The researchers used the Lagrange equation. The researchers also calculated the contribution ratio of each of the labor and capital resources using the Taylor equation, which approximates the Cobb-Douglas function. In a study by [7], they investigated the measurement of technical efficiency and its determinants for Watermelon production in Borno State in Nigeria, for 120 farms that were randomly selected. The random frontier function derived from the Cobb-Douglas production function was used for five inputs, which are the quantity of seeds, area, quantity of pesticides, compound fertilizers, and human labor, and their effect on the dependent variable, which is the volume of Watermelon production per farm. The research concluded that the average technical efficiency was 0.86, and that the most important reasons for the low efficiency are the lack of years of experience and communication with agricultural extension agents, the low size of loans, and the educational level. [8] Measuring Productivity and Technological Change of Watermelon Farms in Diyala Governorate. The study aimed to study the agricultural factors affecting watermelon productivity and to measure technical efficiency and technical change as the two most important components of productivity. The study relied on a questionnaire to provide data randomly collected from 43 watermelon farmers in Diyala Governorate. The relationship between unit area productivity as a dependent variable and human labor and capital as independent variables was studied. The logarithmic function was the best function estimated according to economic, statistical, and standard indicators. The elasticity of labor and capital reached 1.17, meaning that if production elements increase by 10%, productivity will increase by 11.7%, which means there are increasing energy returns. The study recommended the necessity of keeping pace with technological development and increasing capital by providing credit facilities, accompanied by the development and attention to the labor element. [9] A cost-effectiveness study of watermelon production in Tanzania. This study was designed to assess the cost-effectiveness of watermelon production in Rufiji and Mkuranga districts. The study determined the cost-effectiveness of watermelon farmers, identified variations in cost-efficiency across farms of different sizes and capital requirements, and examined the sources of cost inefficiency. A two-stage random sampling method was used to select 200 farmers from the two districts to collect data to achieve the main objectives of the study. Cost efficiency of farms in Mkuranga ranged from 10% to 99%, with an average of 73%. The results of Rufiji showed that farms' EC ranged from 89% to 99%, with an average of 90%. It was found that education level, farm area, capital requirement, and logistics significantly impacted inefficiency. The results indicate that watermelon production is generally cost-effective, and that efficiency is affected by capital requirement and farm area in the study areas.. In a study by [1], they compared the profitability of watermelon and melon production in South Konawi Province, Southeast Sulawesi. Twenty farmers were selected for both crops. After collecting data through a questionnaire, the costs and returns were analyzed, and a t-test was conducted for the independent variables. It was found that watermelon production was more profitable than melon by focusing on growing these two crops because their net return is higher compared to other crops, and they have an impact on increasing farmers' income. A study by [4] entitled "Economic Analysis and Technical Efficiency of Watermelon Production in Niger State, Nigeria" used a multi-stage sampling method to select the sample, from which 150 farmers were selected. Data were collected through a questionnaire to determine the inputs, outputs, and their relative prices. The stochastic frontier function derived from the Cobb-Douglas function was used. The study concluded that watermelon cultivation achieves a total agricultural income of (534,747) naira/hectare, a net income of (459,769) naira/hectare, and a return on investment of (6.13). The study concluded that watermelon cultivation is a profitable project whose production can be increased by increasing the cultivated areas while ensuring that farmers obtain production inputs and provide infrastructure facilities.

In a previous study [2] on the technical efficiency and its determinants for the production of watermelon in Adana province, Turkey, the researchers used the stochastic frontier function derived from the Cobb-Douglas production function for (69) farms, randomly selected and through a questionnaire form, the data for the study were collected, as the cost of producing one kilogram of watermelon amounted to (0.1) dollars, Labor costs constituted the most significant proportion of the total costs, and the farm efficiency ranged between (0.45-1.00) for the sample farms with an average of (0.82). The researchers concluded that farmers are expanding their production by reducing the use of inputs, but they need to organize outputs to ensure savings in production. [10] presented a study on calculating the resources that achieve the economic efficiency of wheat cultivation in Al-Baaj district in Nineveh Governorate using the random frontier function. It was found that there is a direct relationship between the number of irrigations, the amount of pesticides, the area, and wheat productivity, while this production is inversely related to agricultural work, the amount of seeds, and fertilizers. The researchers attributed the reason for this to the use of these resources at a rate that exceeds the factory's need for them, which led to a waste of resources and thus a decrease in efficiency to below the optimal level. In a study by [11] on the determinants of economic efficiency of crystal onion production in Nineveh Governorate for the 2022 agricultural season, in Al-Shekhan District as a model, he focused on the factors that determine onion production and how to calculate their optimal values and compare them with the actual quantities of resources used by crop farmers, as the surplus and deficit in the use of those resources were calculated. Finally, in a study [12], which specialized in analyzing the efficiency of using resources for Watermelon production in the states of Haryana and Karnataka for (120) farmers using multiple sampling technique for the year (2022), the research aimed to know the technologies, inputs, and effective use of resources and measure their efficiency through the Cobb-Douglas production function and relying on the condition of maximization and efficiency (VMP/MFC) estimated from the function, the results showed that the efficiency was positive, indicating an increase in the use of resources, except for the mechanized work, the efficiency value was negative for the state of Haryana, while in Karnataka, the value of (VMP/MFC) was positive, except for the cost of seeds, which was negative. The researchers concluded that the lack of training and awareness, the knowledge gap, and extension services provided to the sample farmers are among the most important reasons for their low efficiency in using resources.

We note from the above studies that they either study maximizing production, minimizing costs, or calculating efficiency using the two-input Cobb-Douglas function. However, in this study, the function was used with three inputs. If the area of the farm was entered, the optimal combinations were calculated in the case of maximizing production or minimizing costs, as well as extracting the isoquant curve equation and then drawing the curves between the inputs to obtain a group of different combinations of resources.

The study aimed to calculate the Cobb-Douglas function using economic theory, statistics, mathematical economics, econometrics, and isoquant curves. In addition, it was to identify optimal resource combinations to maximize profit and minimize cost. Furthermore, it was to determine the optimal use of these resources and compare them with actual agricultural use.

Materials and Methods

The descriptive approach was adopted, based on the concepts of economic theory and reference review.. In addition to the quantitative approach, by choosing the optimal model and method that serves the objectives of the research, through the multiple regression equation using the (OLS) method, calculating the Cobb-Douglas function, and determining the production volume that maximizes profit and minimizes cost. The optimal combinations of production requirements and the amount of the most significant profit were also determined.

Cobb-Douglas is one of the best analytical equations in economics, as it helps economists develop economic models and derive more modern production functions based on it [13]. This function assumes a constant elasticity of production regardless of the actual quantities of inputs [14]. Its formula:

$$Q = b_o X_1^{b1} x_2^{b2}$$

Where Q: production quantities, bo is the constant function or technological change, and (b_1, b_2) represent the production elasticities of resources X_1 and X_2 (number of workers and amount of capital) respectively, and their values range between (0 - 1), thus determining the returns (returns to scale) or returns to scale..

The Cobb-Douglas function has several properties, the most important of which is its homogeneity, which rises to the degree ($b_1 + b_2$). The degree of homogeneity and returns to scale are determined by the sum of elasticities (E), where $E = b_1 + b_2$ [15]. In the ideal case, the values of b_1 and b_2 range between (1-0) [14]. The output curves for the quantity of labor and the value of capital can shift by increasing one of them and keeping the other constant. Their coefficients are also easy to calculate by converting them to the logarithmic form of the natural base (ex), where e = 2.71828 [16], and thus the formula of the function becomes as follows:

$$\mathrm{Ln}\, Q = \mathrm{Ln}\, bo + b_1 \mathrm{Ln}\, X_1 + b_2 \mathrm{Ln}\, X_2$$

The Cobb-Douglas production function can take more than one supplier, as in the following formula:

$Q = b_o X_1^{b1} X_2^{b2} X_3^{b3}$ Its logarithmic formula is:

$$\mathrm{Ln}Q = \mathrm{Ln}\, b_o + b_1\mathrm{Ln}X_1 + b_2\mathrm{Ln}X_2 + b_3\mathrm{Ln}X_3$$

Where: Q: production quantity, b: technical level (function constant)
X_1, X_2, X_3: production factors (labor, capital, farm area)
B_1, b_2, b_3: production factor parameters.

After collecting the required data through a questionnaire for a sample of 32 watermelon farms in the study area, the data were analyzed and interpreted statistically, quantitatively, and economically. The average cultivated area was (6) dunams, representing (25%) of the studied population. The production function was calculated using the Ordinary Least Squares (OLS) method using (Eviews.10). The logarithmic formula was adopted because it gave the best estimates among the independent variables, which are the production elements of human labor and the value of capital, and the dependent variable (Q), the total production of each farm, calculated in tons of watermelon crop for the season (2024), as shown in table (1) below.:

Table (1): Variables adopted in the standard model

variable	The symbol	Unit	Variable description
Production	Q	dunum	Total farm production of watermelon (dependent variable)
human labor	X_1	man/day	The human labor component, whether family or paid, was estimated for the farm for the 2024 season, which comprises all operations required for crop production, such as fertilization, pesticide spraying, irrigation, weeding, harvesting, etc. (the independent variable).
Capital value	X_2	dinar	It represents all costs used in producing the crop, such as fertilizers, whether chemical or organic, pesticides and fungicides, electricity, fuel, oils, equipment and pump maintenance, mechanical labor wages, irrigation costs, and others (in dinars) during the season (2024) (independent variable).
farm area	X_3	dunum	Represents the total farm area planted with the watermelon crop (independent variable).

The mathematical formula below is formulated to find out the relationship between output and its resources:
$Ln\ Q = Lnb_0 + b_1\ Ln\ X_1 + b_2\ Ln\ X_2 + b_3\ Ln\ X_3$
Where: Q is production (kg), X_1 is labor (man/day), X_2 is capital (dinars), X_3 is farm area (dunums)
b_o: Equation constant (technology level)

b_1, b_2, b_3: are variable parameter

Results and Discussion

After entering the data and analyzing it with the help of statistical programs, we obtained:

Table (2): Data analysis results for the Watermelon farms

Variable	Coeffi-cient	Std. Error	t-Statistic	Prob.
C	1.723515	0.960945	1.793561	0.0570
LNX1	0.504770	0.161059	3.134063	0.0038
LNX2	0.384494	0.186712	2.059295	0.0282
LNX3	0.244439	0.134634	1.815583	0.0392
R-squared	0.905034	Mean dependent var	10.20258	
Adjusted R-squared	0.895537	S.D. dependent var	0.451293	
S.E. of regression	0.145861	Akaike info criterion	0.902191-	
Sum squared resid	0.638265	Schwarz criterion	0.722619-	
Log likelihood	19.33724	Hannan-Quinn criterion.	0.840952-	
F-statistic	95.30030	Durbin-Watson stat	1.839405	
Prob(F-statistic)	0.000000			

The table source was prepared based on the questionnaire data and its outputs (Eviews 10). Dependent Variable: LNQ, Method: Least Squares, Date: 09/ 03/ 25 Time: 21:40, Sample: 1 – 34, Included observations: 34

Based on the results of table 2, the estimated production function was written using the multiple linear regression analysis using the least squares (OLS) method, as shown below:

$$\mathbf{Ln\ Q = 1.723 + 0.5048\ X_1 + 0.3845\ X_2 + 0.244\ X_3}$$

A- Statistical Interpretation: Using table (1), the T-test, at a significance level of (0.05), determined the significance of the three independent variables. Using R2, its value of (0.905) indicates that (90.5%) of the effects on the dependent variable are due to the explanatory variables (X_1, X_2, X_3). The remaining 9.5% are due to other factors or the random variable. The significance of the equation as a whole was determined by the F-test, which reached 95.3% at a significance level of 0.01 [17].

B- Standard Interpretation: To test for the problem of autocorrelation, the (D.W) test was used, which showed no problem between the values of the random variable or the error term, with a significance level of 0.05 (Ahmed et al., 2023). By extracting the tabular value of du, it was found to be equal to 1.652. The sample consisted of 34 farms, and the independent variables were 3. This means that the calculated value is in the acceptance region, explaining the absence of this problem (du < D.W < 4-du), i.e. (1.652< 1.84< 2.16). The problem of heterogeneity of variance remains, which many researchers suffer from, especially in cross-sectional data. This problem was tested using the (Park) test, which is always used to test this problem [18]. By taking the logarithm of the square of the residuals ($Lnei^2$) as the dependent variable, and adopting the logarithm of the explanatory variables as independent variables, and using Eviews 10, the results were below:

Table (3): Results of Park's test for heteroscedasticity

Independent variables	Check-square test with explanatory variables	R^2	F
Number of workers LnX_1	$Lnei^2 = -3.85 - 0.488 \ Ln X_1$ t (-0.615) (-0.345)	0.037	0.119
Capital LnX_2	$Lnei^2 = -9.9 - 0.257 \ Ln X_2$ t (-0.478) (-0.189)	0.011	0.035
Farm area LnX_3	$Lnei^2 = -4.7 - 0.75 \ Ln X_3$ t (-2.01) (-0.57)	0.01	0.33

The table source was prepared based on the questionnaire data and its outputs (Eviews 10).

From Table (3), we find, through the t-value, that the explanatory variables are not significant below the 0.05 significance level. When comparing the table value with the calculated value, we find that the calculated value is lower than the table value. The F-test reveals that the function as a whole is not significant when comparing the calculated value with the table value. We conclude from this that the problem of heteroscedasticity of variance does not exist. Finally, the Klein test was adopted to detect the problem of multicollinearity [19]. The correlation coefficient between the explanatory variables was compared with the root of the coefficient of determination, and its value reached 0.951. It was found that all values of the correlation coefficient were less than the root of the coefficient of determination, which confirms the absence of this problem. Table (3) shows the values of the correlation coefficients between the studied variables.

Table (4): Correlation Matrix between Explanatory Variables

Correlation			
	LNX1	LNX2	LNX3
LNX1	1.00000	0. 50728	0.44982
LNX2	0.50728	1.00000	0.65955
LNX3	0.44982	0.65955	1.00000

The source of the table was prepared by the researcher, based on the questionnaire and outputs (Eviews 10).

Economic interpretation of the function

$\text{Ln } Q = 1.723 + 0.5048\ X_1 + 0.3845\ X_2 + 0.244\ X_3$

$Q = 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244}$

Exponential formula

- The statistical, mathematical, economic, and econometric estimation results of the function parameters confirm the positive relationship between the independent variables (human labor X_1, capital value X_2, farm area X_3) and the production variable (Q). This is consistent with economic theory. Since the function is a double logarithmic, the coefficient of the variable represents its production elasticity, i.e., an increase in the quantity produced by each parameter (X_1, X_2, X_3) if its use increases by 1% for each. Since the elasticity of the variables lies between 0-1, this means that these resources are operating in the second stage of production. From the production function, it becomes clear that the total elasticity, which is the sum of the production elasticities for (X_1, X_2, X_3), reached (1.133), which is greater than one, which means that the function reflects the state of increasing returns to scale, indicating the possibility of continuing to increase the level of production. As for the contribution of each element to production, it was calculated as follows: [17]
- The percentage of resource contribution to production = resource production elasticity / total elasticity × 100. It was found that labor was the primary resource, followed by capital and farm area, with percentages of (44.54%, 33.93%, and 21.53%), respectively.

The optimal resource mix that achieves the optimum level of output that maximizes profit

To calculate the optimal resources or production elements (human labor, capital value, and farm area) that achieve the production volume that maximizes profit, we create the objective function (objective function), which represents the normalized profit function [20]. The following have been done:

$\text{Ln } Q = 1.723 + 0.5048\ X_1 + 0.3845\ X_2 + 0.244\ X_3$

$Q = 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244} ----1$

$\pi = \mathrm{P}_Q \cdot \left(b_o \mathrm{X}_1^{b1} \mathrm{X}_2^{b2} \mathrm{X}_3^{b3}\right) - \lambda(\mathrm{Px}_1.\ X_1 + \mathrm{Px}_2.\ X_2 + \mathrm{Px}_3.\ X_3 - \overline{\mathrm{TC}})$ aim equation for profit

$\pi = 325(5.604\, X_1^{0.5048} X_2^{0.3845} X_3^{0.244}) - \lambda(15000X_1 + 1.04X_2 + 150000X_3 - 6568548)$

Where:

π: Objective function (profit function)

P_Q: Output price (average price of watermelon is 325 dinars/kg)

b_o: Technical level, X_1, X_2, X_3: Production factors (labor, capital, and farm area, respectively)

P_{X1}: Labor wage (average wage for workers on watermelon farms is 15,000 dinars per person/day)

P_{X2}: Interest on capital (interest rate is 0.08 per year). Since watermelons are grown and marketed within four months, i.e., less than half a year, the interest rate will be 0.04, and therefore the return per dinar is 1.04.

P_{X3}: Rent per dunum (average rent per dunum for the watermelon period is approximately 150,000 dinars, mainly since the crop is grown with tomatoes in the study area, so the rent is divided between the two crops),

b_1, b_2, b_1: Function parameters (production elasticity of each factor)

$\overline{TC}$: Actual cost (average farm cost is 6,568,548 dinars)

λ: Landa (Lagrange multiplier)

By applying the condition of glorification

$VMPx_i = Px_i \rightarrow \frac{P_Q MP_{Xi}}{P_Q MP_{Xn}} = \frac{P_{Xi}}{P_{Xn}}$

We derive the profit function for the variables (X_1, X_2, X_3, λ) as follows:

$$\frac{\partial \pi}{\partial X_1} = (325)(5.604)(0.5048)\, X_1^{0.5048-1}\, X_2^{0.3845}\, X_3^{0.244}) - 15000\,\lambda = 0$$

$$= (919.392\, X_1^{-0.4952}\, X_2^{0.3845}\, X_3^{0.244}) = 15000\,\lambda ----\mathbf{2}$$

$$\frac{\partial \pi}{\partial X_2} = (325)(5.604)(0.3845)X_2^{0.3845-1}X_1^{0.5048}\, X_3^{0.244}) - 1.04\,\lambda = 0$$

$$= (700.29\, X_2^{-0.6155}\, X_1^{0.5048}\, X_3^{0.244}) = 1.04\,\lambda ------\mathbf{3}$$

$$\frac{\partial \pi}{\partial X_3} = (325)(5.604)(0.244)\, X_3^{0.244-1}\, X_1^{0.5048}\, X_2^{0.3845}) - 150000\,\lambda = 0$$

$$= (444.4\, X_3^{-0.756}\, X_1^{0.5048}\, X_2^{0.3845}) = 150000\,\lambda ------\mathbf{4}$$

$$\frac{\partial \pi}{\partial \lambda} = (15000\, X_1 + 1.04\, X_2 + 150000\, X_3 - 6568548) = 0 ---\mathbf{5}$$

By dividing equation (2) by (3), we obtain the equation (expansion path) for (X_1, X_2).

$$= \frac{(919.392X_2)}{(700.29X_1)} = \frac{15000\,\lambda}{1.04\,\lambda} \Rightarrow 956.168\, X_2 = 10504350\, X_1$$

$X_1 = 0.000091026\, X_2$ ------------- 6

The result of dividing (3 by 2) is the expansion path for (X_1, X_2).

$$= \frac{(700.29\, X_3)}{(444.4\, X_2)} = \frac{1.04\,\lambda}{150000\,\lambda} \Rightarrow 105043500X_3 = 462.176X_2$$

$X_3 = 0.0000044\, X_2$ ------------- 7

By substituting (6, 7) into (5), we extract the optimal capital value:

$15000\ (0.000091026\ X_2) + 1.04\ X_2 + 150000\ (0.0000044\ X_2) - 6568548 = 0$

$1.3654\ X_2 + 1.04\ X_2 + 0.66\ X_2 = 6568548 \Rightarrow 3.0654\ X_2 = 6568548$

$X_2 = \frac{6568548}{3.0654} = 2142803$ dinar (Optimum capital maximizing profit)

By substituting **(**2142803**)** in **(**6**)** the optimal number of workers and in **(**7**)** we find the optimal area of the farm

$X_1 = 0.000\mathbf{091026}\ (2142803) = 195.05$ man/day (The optimal number of workers that maximizes profit)

$X_3 = 0.0000044\ (2142803) = 9.43$ dunum**)** Optimal farm area for maximum profit)

We substitute the quantities of resources calculated above into function (1) and obtain the quantity of production achieved to maximize profits.

$Q = 5.604\ (195.05)^{0.5048}\ (2142803)^{0.3845}\ (9.43)^{0.244}$

$Q = 5.604\ (14.33)\ (271.808)\ (1.73) = 37762$ kg **(**Optimal and profit-maximizing production volume**)**

The optimal civil resource combination of costs and profit maximization:

The second method for maximizing profit and achieving optimal economic efficiency is by minimizing costs. This is achieved by constraining production ($\overline{Q}$) and compensating for factor prices, which leads to the lowest cost line tangent to the isoquant [21]. Therefore, we will constrain production and form the objective function below.

$TC = 15000\ X_1 + 1.04\ X_2 + 150000\ X_3\ ,\ Q = 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244}$

Since the actual production volume of the farm ($\overline{Q}$) reached an average of (**29040**) kg, We form the objective function (U) using the Lagrange multiplier (θ)

$U = (Px_1.\ X_1 + Px_2.\ X_2 + Px_3.\ X_3) + \theta\ (\overline{Q} - 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244})$ aim equation

$U = (15000\ X_1 + 1.04\ X_2 + 150000\ X_3) + \theta\ (29040 - 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244})$--- (1)

We extract the partial derivative of (X_1, X_2, X_3, θ)

$$\frac{\partial U}{\partial X_1} = 15000 - \theta\ (5.604)\ (0.5048) X_1^{0.5048-1}\ X_2^{0.3845}\ X_3^{0.244} = 0$$

$$15000 = \theta\ 2.8289\ X_1^{-0.4952}\ X_2^{0.3845}\ X_3^{0.244} ------ (2)$$

$$\frac{\partial U}{\partial X_2} = 1.04 - \theta\ (5.604)\ (0.3845) X_2^{0.3845-1}\ X_1^{0.5048}\ X_3^{0.244} = 0$$

$$1.04 = \theta\ 2.15474\ X_2^{-0.6155}\ X_1^{0.5048}\ X_3^{0.244} ------ (3)$$

$$\frac{\partial U}{\partial X_3} = 150000 - \theta\ (5.604)\ (0.244) X_3^{0.244-1}\ X_1^{0.5045}\ X_2^{0.3845} = 0$$

$$150000 = \theta\ 1.36738\ X_3^{-0.756}\ X_1^{0.5045}\ X_2^{0.3845} ------- (4)$$

$$\frac{\partial U}{\partial \theta} = 29040 - 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244} = 0 ------ (5)$$

By dividing (2) by (3), we obtain the equation (expansion path) for (X_1, X_2)

$$\frac{15000}{1.04} = \frac{2.8289\ X_2}{2.15474\ X_1} \Rightarrow 32321.1\ X_1 = 2.94206\ X_2 \quad \text{Expansion path equation}$$

$X_1 = 0.000091026\, X_2 ------ (6)$

We divide (3) by (4) to find the expansion path to (X_2, X_3)

$$\frac{1.04}{150000} = \frac{2.15474\, X_3}{1.36738\, X_2} \Rightarrow 1.422075\, X_2$$
$$= 323211\, X_3 \quad \text{Expansion path equation}$$

$X_3 = 0.0000044\, X_2 ------ (7)$

We substitute (6,7) into 5 to find the urban cost value of (X_2).

$$29040 - 5.604\,(0.000091026\, X_2)^{0.5048}\,(X_2)^{0.3845}\,(0.0000044\, X_2\,)^{0.244} = 0$$

$$29040 = 5.604\,(0.009124)\, X_2^{0.5048}\, X_2^{0.3845}\,(0.04932)\, X_2^{0.244}$$

$$29040 = 0.002522\, X_2^{1.1333} \Rightarrow X_2^{1.1333} = \frac{29040}{0.002522}$$

$X_2 = (11514670)^{0.8823789} = 1700981$ denar (The civil capital value of costs)

Substituting 1,700,981 into 6.7, we find the number of workers and the civil area for costs.

$X_1 = 0.000091026\,(1700981) = 154.84$ Man/Day (human labor)

$X_3 = 0.0000044\,(1700981) = 7.48$ donum (optimum area for urban farm for costs)

Substituting civilian quantities into the output function results in the farmers' actual production. Substituting the civilian quantities into the cost equation results in the lowest cost that achieves efficiency and maximizes profits, as shown below:

$Q\ 5.604\,(154.84)^{0.5048}\,(1700981)^{0.3845}\,(7.48)^{0.244}$

$Q = 5.604(12.75)\,(248.72)\,(1.634) = 29040$ kg

$TC = 15000\,(154.84) + 1.04\,(1700981) + 150000\,(7.48)$

dinar (lowest possible cost for $TC = 2322600 + 1769020 + 1122000 = 5213620$ the farm)

Iso quant curve

The isoquant curve is defined as the geometric locus of different combinations of production factors that yield the same output, assuming the number of these factors remains constant and the factor under study varies. [14]. We will find the equation of the isoquant curve using four levels of output.

We estimate the isoquant curve for (X_1, X_2), fixing X_3 at its mean and X2 changing, at four levels of output (25,000, 30,000, 35,000, 40,000) kg/farm, and at the optimal quantities. For example, at an output volume of (25,000) kg and a capital of (1,500,000) dinars, and fixing the farm area at its arithmetic mean of (6) dunums/farm, we will obtain many workers of (141) man/day. By repeating these levels of capital value and production, we obtain different numbers of workers. By projecting these numbers onto their coordinates, we solve for four equal-yield curves for combinations of number of workers, capital value, and constant farm area, as follows:

$Q = 5.604\, X_1^{0.5048}\, X_2^{0.3845}\, X_3^{0.244}$

$$= \frac{Q}{5.604\ X_2^{0.3845}\ X_3^{0.244}} \Rightarrow X_1 = \left(\frac{25000}{5.604\ X_2^{0.3845}\ X_3^{0.244}}\right)^{1.981} X_1^{0.5048}$$

$$X_1 = \left(\frac{25000}{5.604\ (1500000)^{0.3845}\ (6)^{0.244}}\right)^{1.981} \Rightarrow X_1 = \left(\frac{25000}{5.604\ (236.978)(1.548)}\right)^{1.981}$$

$$X_1 = \left(\frac{25000}{2055.78}\right)^{1.981} \quad \Rightarrow X_1 = 141 \text{ man/day}$$

By compensating for the profit-maximizing capital value, farm area, and the output that achieves the maximum profit, we get the optimal number of human workers who are entitled to the maximum profit:

$$X_1 = \left(\frac{37762}{5.604\ (2142803)^{0.3845}\ (9.43)^{0.244}}\right)^{1.981} \Rightarrow X_1 = \left(\frac{37762}{5.604\ (271.808)(1.73)}\right)^{1.981}$$

$$X_1 = \left(\frac{37762}{2635.16}\right)^{1.981} \quad \Rightarrow X_1 = 195 \text{ man/day (Optimal number of workers)}$$

When using the optimal combination of capital, space, and civil output resources for costs, we obtain the optimal number of civil human labor for the cost.

$$X_1 = \left(\frac{29040}{5.604\ (1700981)^{0.3845}\ (7.48)^{0.244}}\right)^{1.981} \Rightarrow X_1 = \left(\frac{29040}{2277.372}\right)^{1.981} \Rightarrow X_1 = 154.9$$

Table (5): The isoquant curve between (X_2, X_1) with (X_3) fixed at its average and four levels of production

Production levels (kg) → 25000			**30000**	**35000**	**40000**
Capital X_2 (dinar)	**Farm area X_3 (dunum)**	**Work X_1 (man/day)**			
1500000	6	141.0	202.3	274.5	357.7
2000000	6	113.2	162.5	220.5	287.3
2500000	6	95.5	137.1	186.0	242.4
3000000	6	83.1	119.3	161.9	211.0
3500000	6	73.9	106.1	144.0	187.6
4000000	6	66.8	95.8	130.1	169.4
4500000	6	61.1	87.6	118.9	154.9
5000000	6	56.3	80.9	109.7	143.0

The table was prepared based on the results of the output function.

By repeating the above but between (X_2, X_3), and fixing (X_1) at its average of (86) factors, the result will be in Table (6). If we use the optimal resource combinations, whether maximizing or minimizing, for work and area, we will obtain the capital values in maximizing and minimizing, and this also applies to area. By repeating it between (X_1, X_3), and fixing (X_2) at its average of (4,378,548) dinars, the result will be in table (7).

Table (6): The equal-production curve between (X_3 and X_2) with (X_1) fixed at its average and four production levels

Production levels (kg)	→	25000	30000	35000	40000
Farm area X_3 (dunum)	Work X_1 (man/day)	Capital X_2 (dinar)			
4	86	3694975	5935848	8862258	12540749
5	86	3207242	5152322	7692450	10885384
6	86	2856927	4589554	6852233	9696414
7	86	2590766	4161974	6213854	8793062
8	86	2380335	3823925	5709144	8078859
9	86	2208955	3548609	5298096	7497196
10	86	2066133	3319171	4955543	7012459
11	86	1944907	3124425	4664786	6601016

The table was prepared based on the results of the output function.

Table (7): The isoquant curve between (X_1, X_3), fixing (X_2) at its average, and four levels of production

Production levels (kg)	→	25000	30000	35000	40000
Work X_1 (man/day)	Capital X_2 (dinar)	Farm area X_3 (dunum)			
80	4210142	3.8	8.0	15.1	26.1
90	4210142	3.0	6.3	11.9	20.5
100	4210142	2.4	5.1	9.5	16.5
110	4210142	2.0	4.2	7.8	13.5
120	4210142	1.6	3.5	6.5	11.3
130	4210142	1.4	2.9	5.5	9.6
140	4210142	1.2	2.5	4.8	8.2
150	4210142	1.0	2.2	4.1	7.1

The table was prepared based on the results of the output function.

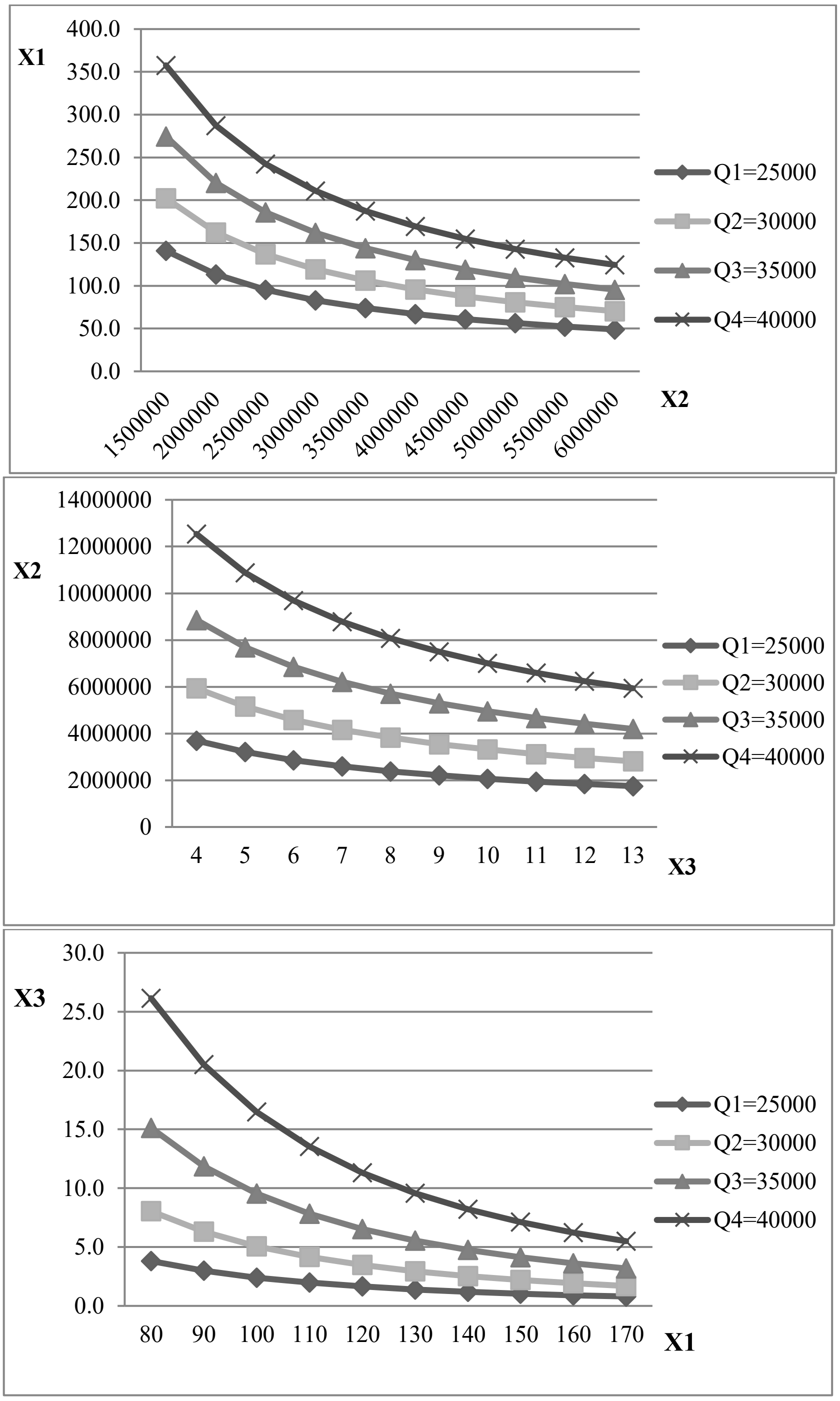

Figure (1): The isoquant curves between resources for various levels of production.
Source: Based on data from Tables (4), (5), (6).

Profits using combinations of maximizing, civil, and actual resources

The profit achieved at the level of production that achieves the maximum profit can be calculated using the profit equation by substituting the quantities of resources that achieve the maximum profit in the cost function and substituting the optimal production volume, as shown below: [16]

$Q = 5.604\, X_1^{0.5048}\, X_2^{0.3845}\, X_3^{0.244}$, $P_Q = 325$ dinar/kg , $TC = 15000 \times 195.23 + 1.04 \times 2144760 + 150000 \times 9.44$, $\pi = TR - TC$, $TR = P_Q \times Q$, $Q = 37775$ kg

$\therefore \pi = 325\ (37762) - (15000\times 195.05 + 1.04\times 2142803 + 150000\times 9.43)$

$\pi = 12272650 - 6568548 = 5704102$ dinar (The greatest profit achieved by the farm)

The profit resulting from reducing costs is extracted by substituting the quantities of the civil cost elements in the cost function and substituting the quantity of actual production.

$Q = 5.604\ X_1^{0.5048}\ X_2^{0.3845}\ X_3^{0.244}$, $TC = 15000 \times 154.84 + 1.04\times 1700981 + 150000 \times 7.48$

We compensate for the actual production level of (29040) kg

$\pi = (325 \times 29040) - [15000 \times 154.84 + 1.04 \times 1700981 + 150000 \times 7.48]$

$\pi = 9438000 - 5213620 = 4224380$ dinar (The profit achieved by the farm by reducing costs)

- The actual profits of the Watermelon farmers are:

$\pi = (325 \times 29040) - (6568548) = 2869452$ dinar

The optimal combination of elements at the level of profit-maximizing output of (37762) kg/farm amounted to (195) working days, (2142803) dinars of capital, and (9.43) dunums of farm area, which gave a net profit of (5704102) dinars per farm. As for the quantities of civil production elements for costs, they amounted to (155) human working days, (1700981) dinars of capital value, (7.48) dunums of farm area, and a profit of (4224380) dinars per farm. While the actual profits of watermelon farmers amounted to (2869452) dinars, from their actual production volume of (29040) kg, using actual labor, capital, and cultivated area (86 working days, 4210142 dinars, and six dunums), respectively. From the above, it is clear that the profit achieved at the profit-maximizing production level, or the cost-effectiveness profit, exceeds the farm's actual profit. This requires increasing the use of labor, reducing the use of capital, and increasing the farm's area, given its importance in increasing production volume and maximizing farmers' profits, thus achieving economic efficiency [22].

The results we have reached in this study vary with respect to the quantities of different production elements, whether by restricting costs or output to maximize profit, and the possibility of reducing the use of capital, which is offset by increasing the number of workers and the area of the farm, as they play a role in increasing the quantity of output and reducing costs, which is directly reflected in maximizing farmers'profits, and the possibility of obtaining multiple combinations of resources using the equation of equal quantity curves at different production levels, in addition to reaching the optimal quantities of resources that maximize profit and reduce cost.

From the above, we recommend the need to rationalize the use of capital and reduce its waste, especially concerning fertilizers, both chemical and organic, pesticides (both insecticides and fungicides), mechanical work costs, and irrigation costs, within the optimal quantities determined by specialists. Furthermore, the use of labor and cultivated area should be increased, which in turn leads to reduced overall costs and increased farmers' profits due to increased production or reduced costs, thus achieving economic efficiency. In addition, farmers should be assisted by all available means to achieve optimal quantities of available resources to maximize profits and fully utilize the available space for this purpose.

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