

# Economic Analysis of the Optimal Production Scale for Cucumber Production in Nineveh Governorate, 2025

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**Abstract:** The study aimed to estimate the optimal production volumes and economic areas for cucumber production in Nineveh Governorate, using the districts of Mosul, Hamdaniya, Tel Keif, Tal Afar, Al-Baaj, and Al-Hadar as an applied model. This was achieved by estimating cost functions and analyzing economies of scale, as well as measuring the economies of scale realized by the crop producers through calculating the elasticity of the average cost function and the coefficient of the estimating function, The study relied on field data collected using a questionnaire administered via random sampling. The sample size consisted of 100 farms, distributed across both surface and drip irrigation systems. To determine the optimal yield for cucumbers, cubic cost functions were estimated as the most suitable for the field data and consistent with economic and statistical logic. The results showed that the optimal yield was approximately 7.2 tons in surface-irrigated farms, While yields reached approximately 15.5 tons in drip-irrigated farms, the results also showed that the majority of cucumber farmers in the study sample were unable to achieve optimal production volumes in both irrigation methods. This reflects production deviations from the economically efficient level. In light of these findings, the study recommends the implementation of applied agricultural extension programs based on cost function analysis and farm classification according to efficiency levels, with the aim of transferring expertise from efficient farms to less efficient ones, reducing waste in key production inputs, and improving the overall economic efficiency of cucumber production.

**Keyword:** Economic Analysis ; Optimal Production Scale ; Cucumber Crop ; Nineveh

## INTRODUCTION

The vegetable production sector is a vital agricultural sector of economic and nutritional importance, characterized by rapid capital turnover and high economic returns per unit area, in addition to its key role in providing the population's nutritional needs for essential elements. Cucumbers are among the most economically and consumer-wise important vegetable crops in Iraq due to high domestic demand and their consistent inclusion in daily diets, In addition to its suitability for greenhouse and open-field cultivation, which grants it wide production flexibility compared to many other crops (Al-Qaisi, 2018), Nineveh Governorate is considered one of the main agricultural governorates in Iraq due to its natural and human resources suitable for agricultural production. These resources include fertile soil, diverse climatic conditions, and the availability of agricultural expertise, making it a promising region for vegetable production, especially cucumbers, However, the agricultural sector in the governorate faces increasing economic and production challenges, including high input costs, fluctuating agricultural product prices, inefficient use of economic resources, and limited adoption of modern technologies in agricultural management and production. This has led to a clear disparity among producers in terms of productivity, profitability, and economic efficiency (Alhayali et al., 2026). From an agricultural production economics perspective, achieving economic efficiency requires the optimal use of production factors to maximize profits or minimize costs, Optimal production volume is a fundamental concept in the economic theory of production. It represents the production level at which the best economic relationship between inputs and outputs is achieved, ensuring the lowest average cost and the highest possible economic return. This concept is also linked to technical, economic, and allocation efficiency, which are key indicators in evaluating the performance of agricultural production units (Debertin, 2012). The study of the economics of cucumber production is of great importance because it not only analyzes production aspects but also includes analyzing the economic relationships between different factors of



production, estimating production and cost functions, measuring economic elasticities, and determining the efficiency of agricultural resource utilization, This is especially relevant given the rising costs of agricultural production and current economic changes, which necessitate reliance on scientific economic analysis to rationalize production decisions and direct resources towards their most efficient use (Naji, 2016). Cost function analysis is a fundamental tool in agricultural economic studies, as it contributes to determining the production volume that achieves economic equilibrium between revenues and costs, and thus reaching the optimal production volume that achieves the highest possible economic profit. From this perspective, this study analyzes the reality of cucumber production in Nineveh Governorate during the 2025 production season by estimating the optimal sizes of land and production and measuring the economies of scale achieved by producers, based on the elasticity of the average cost function and the coefficient of the estimating function, This contributes to diagnosing the reality of farmers' economic efficiency and productivity (Waqaf et al., 2016). Several previous studies have highlighted the importance of this type of analysis. For example, Dawood and Mohammad's (2018) study on estimating and analyzing the cucumber production function in greenhouses in Erbil Governorate showed that most farms operate within an uneconomical production phase, necessitating improved resource utilization efficiency to achieve optimal production volume. Similarly, Aziz and Huseen's (2023) study on the economics of cucumber production in Sulaymaniyah Governorate demonstrated a discrepancy between actual and optimal economic production levels in different production systems, This reflects a waste of resources and a lack of efficiency in their use. The research problem lies in the low economic efficiency and productivity of cucumber farmers in Nineveh Governorate due to a lack of knowledge about optimal production volumes and levels of economic efficiency, as well as a limited awareness of the extent of waste in agricultural resource use. This leads to decreased productivity, increased production costs, and a decline in farmers' economic returns, especially given the high prices of production inputs, a large portion of which are imported. Therefore, it is necessary to achieve optimal use of economic resources and raise the level of production efficiency to improve cucumber crop productivity and maximize the economic return for agricultural units, The importance of the study stems from its endeavor to provide a scientific basis that can be relied upon in formulating agricultural policies, improving the efficiency of allocating productive resources, and helping agricultural producers to make more efficient and profitable production decisions. It also aims to support sustainable agricultural development plans by improving production and productivity levels and enhancing the competitiveness of the cucumber crop in local markets. The study aims to analyze the economic reality of cucumber production in Nineveh Governorate by estimating the optimal production volumes and agricultural areas and estimating the economies of scale achieved by farmers, in order to determine the optimal production volume that achieves the highest economic efficiency during the 2025 production season, This contributes to maximizing economic returns and improving the exploitation of available agricultural resources, while the research assumes a weakness in the ability of farmers to maximize their profits as a result of the achieved production levels deviating from technically and economically efficient levels, in addition to the difference between actual production volumes and the optimal production volume and agricultural area that achieves the lowest level of costs and the highest possible economic return.

## MATERIAL AND METHODS

I used a questionnaire form for a random sample of cucumber farmers in Nineveh Governorate (Mosul, Hamdaniya, Tel Keif, Tal Afar, Baaj and Hatra districts) as an applied model for the 2025 production season. 100 questionnaire forms were distributed (25 for surface irrigation, 75 for drip irrigation) to a random sample of all farmers in the study population. Statistical data were collected through personal interviews with members of the sample, which included various information about production, costs, cultivated areas, etc, The data were processed and analyzed using the statistical software Eviews 12. The Ordinary Least Squares (OLS) method was used to estimate the model parameters. This method is one of the most widely used in estimating econometric model relationships due to its inherent characteristics such as unbiasedness and minimal variance, as well as the ease with which it can be calculated. (Al-Adhari, 2010)





Using the least squares (OLS) method, the short-run total cost function for cucumber crops was estimated according to surface irrigation and modern irrigation techniques (drip irrigation), and it was found to be consistent with economic logic and passed statistical and econometric tests, as follows:

### 1- Surface Irrigation

The short-run total cost function was estimated using the flood irrigation method for the cucumber crop and was consistent with economic logic in terms of statistical, econometric and economic tests, as follows:

$$SRTC = 118.027 + 365.866Q - 0.000002157Q^2 + 0.00000022106Q^3 - 0.003AQ + 0.0007A^2$$

TABLE (1): Short-run total cost function of cucumber crop

Independent Variables	Estimated Parameters	Statistical Parameters
Q	365.866 (3.743)	R <sup>2</sup> = 0.72
Q <sup>2</sup>	- 0.000002157 (- 2.201)	R <sup>2</sup> = 0.65
Q <sup>3</sup>	0.00000022106 (2.078)	F = 10.018
AQ	- 0.003 (- 2.638)	D.W = 2.001
A <sup>2</sup>	0.0007 (3.858)	n = 25

Source: Calculated using Eviews 12 software based on questionnaire data

When writing the function in its implicit form, we get:

$$V = C - 365.866Q + 0.000002157Q^2 - 0.00000022106Q^3 + 0.003AQ - 0.0007A^2$$

Taking its first partial derivative with respect to the cultivated area (A) and setting it equal to zero, we obtain:

$$\frac{\partial V}{\partial A} = 0.003Q - 0.004A = 0$$

$$A = 2.142 Q$$

By substituting the value of A into the original function and summing the terms of Q<sup>2</sup>, we obtain the long-run surface irrigation cost function for cucumber crop:

$$LRTC = 365.866Q - 0.00321Q^2 + 0.00000022106Q^3$$

Long-run cost function for cucumber crop under surface irrigation

### Statistical Analysis

The statistical analysis began after verifying the economic consistency of the estimated parameters of the cucumber production model under surface irrigation, particularly with respect to the expected signs in line with economic theory. Subsequently, statistical criteria were evaluated. The estimated parameters were found to be statistically significant, as indicated by the t-test, which confirmed the individual significance of the coefficients. Moreover, the F-test demonstrated that the overall model was statistically significant at the 5% level. The coefficient of determination (R<sup>2</sup>) indicated that approximately 72% of the variation in total cucumber output was explained by the independent variables included in the model, while the remaining 28% was attributed to other unobserved factors not captured within the specification.

### Econometric Analysis



From an econometric perspective, several diagnostic tests were conducted to ensure model validity. Regarding autocorrelation, the Durbin–Watson statistic ( $DW = 2.001$ ) indicated that the model is free from first-order serial correlation, as the value falls within the acceptance region ( $1.89 < DW < 2.11$ ), implying no evidence of positive or negative autocorrelation in the disturbance term. With respect to multicollinearity, the model was considered free from severe multicollinearity problems. Although polynomial terms such as  $Q^2$  and  $Q^3$  are mathematically related to  $Q$ , the relationship is nonlinear in functional form, which reduces concerns regarding perfect linear dependence among explanatory variables in the econometric specification. To test for heteroskedasticity, the study employed the Park test, which involves regressing the logarithm of the squared residuals on the logarithm of output. The estimated auxiliary regression for surface irrigation cucumber production was specified as:  $\log(e_i^2) = 1.091 + 0.760 \log(Q)$ . The results indicated t-values of (0.521) and (0.386) for the constant and slope coefficients respectively, with  $R^2 = 0.024$ ,  $F = 0.077$ , and  $DW = 2.175$ . The model was statistically insignificant at the 5% level according to the F-test, and the t-statistics were below their critical values. Accordingly, the null hypothesis of homoskedasticity cannot be rejected, indicating that no heteroskedasticity problem is present in the model.

### Economic Analysis

The economic analysis focuses on the practical implications of the long-run cost function, particularly in estimating optimal production levels and cultivated areas for cucumber under surface irrigation. This includes the derivation of average cost, marginal cost, cost elasticity, and the parameters of the estimated cost function, which together provide a basis for determining economically efficient production scales.

### Determining the optimal civil production volume for costs of cucumber crop using flood irrigation

In order to calculate the optimal size that minimizes costs (economies of scale) in cucumber production, it is first necessary to find the Long Run Average Total Cost (LRATC) equation, since all production costs are considered variable costs in the long run. The average cost equation was derived from the total cost equation by dividing the latter by the output size  $Q$ , and the Long Run Average Total Cost equation was as follows:

$$LRATC = 365.866 - 0.00321 Q + 0.00000022106 Q^2$$

In order to determine the optimal production volume that minimizes costs, the first necessary condition for minimizing the cost function must be applied, which is to take the first derivative of the average total cost function with respect to output and set it equal to zero, and then solve the equation with respect to  $Q$ , to obtain:

$$\frac{\partial LRATC}{\partial Q} = -0.00321 + 0.000000442 Q = 0$$

$$Q = 7262.443 \text{ kg/don}$$

$$Q = 7.262 \text{ Ton}$$

Optimal production size that minimizes costs for the cucumber crop under flood irrigation in Nineveh Governorate for the districts included in the research sample.

### Determining the optimal areas for cucumber cultivation using flood irrigation:

To obtain the optimal areas planted with cucumbers using flood irrigation in Nineveh Governorate, we substitute the value of  $Q$  for each crop into the value of  $A$ , obtaining:

$$A = 2.142 Q$$

$$A = 2.142 (7.262) = 15.5 \text{ don}$$

This is the optimal area that can be cultivated by cucumber growers to obtain the optimal size of production that minimizes the average long-term cost.

**TABLE (2): Actual and Optimal Production Levels and Cultivated Areas of Cucumber in Nineveh Governorate, 2025**

Crop	Actual Area (donum)	Optimal Area (donum)	Efficiency %	Actual Output (tons)	Optimal Output (tons)	Efficiency %
Cucumber	10.12	15.5	65.2	5.68	7.262	78.2

**Source:** Calculated by the researcher based on questionnaire data

Table (2) shows that the optimal size of the cultivated areas of cucumber crop, which is (15.5) dunams, exceeds the actual size of the cultivated areas of it in Nineveh Governorate. Farmers of this crop must expand their areas by (5.38) dunams. Also, the optimal size of production came with rates that exceed the actual rates of the crop in the study sample, as the optimal sizes of production reached (7.262) tons. Since the optimal sizes of production exceed the actual sizes, farmers of the crop must increase their production by (1.582) tons.

**Realized Scale Economies and Cost Elasticities for Cucumber under Surface Irrigation (Study Sample)**

According to economic theory, production levels below the optimal level achieve increasing rates of economies of scale, and upon reaching the optimal production level, they achieve a constant level of scale. However, production levels above the optimal level achieve decreasing rates, resulting in no economies of scale. This can be calculated quantitatively according to the following formula:

$$Economies = \frac{LRACm - LRACi}{LRACm - LRACo} \quad (\text{Melemore, et al, 1983})$$

**Where:**

Eco = Economies of scale (realized scale economies).

LRACm = Long-run average total cost at the lowest observed production level.

LRACi = Long-run average total cost at production level i.

LRACo = Long-run average total cost at the optimal production level.

As for cost elasticity, it was calculated using the following formula:

$$Elasticity = \frac{\Delta LAC}{\Delta Q} \cdot \frac{Q}{LAC} \quad (\text{Ferguson, 1975})$$

Table (3, 4) shows that the average total cost starts to rise after the optimal production level, and then continues to rise as production continues to expand, since economies of scale increase as the average total cost curve decreases until the economies of scale reach (100%), which is the stage of (stable yield) at the optimal production size. At this stage, there is the (stage of increasing yield), in which the average total cost curve decreases as the farm size expands, achieving increasing rates of economies of scale, Economies of scale occur due to two factors: one is the expansion of specialization and division of farm work, and the other is the increased possibility of using modern methods in agricultural production. This leads to a reduction in the average unit costs of output. However, when the farm continues to increase in size, economies of scale appear as a result of establishing production capacities larger than those with which the advantages of large-scale production are achieved. This will result in a decrease in farm performance efficiency, and will then lead to a rise in the average total cost curve after the optimal size of production. This stage of production is called the stage of diminishing returns.

The results showed that the elasticity of the cost function takes a negative sign at production levels below optimum, indicating an inverse relationship between output and average cost. This means that the average total cost decreases as output increases. Conversely, the elasticity of the cost function takes a positive sign at production levels above optimum,





reinforcing the direct relationship between output and average cost at production levels above optimum. In other words, the average total cost increases as output increases beyond optimum.

The coefficient of the function showed that its value is positive, greater than one, for production levels below optimum. Its value increases with increasing production volume, meaning that the rate of increase in production volume exceeds the rate of increase in costs, which is characteristic of the first stage of production (the stage of increasing returns). Knowing the marginal cost allows us to infer the achieved economies of scale. In the region of economies of scale, the marginal cost function is below the average total cost function. When the two cost curves (marginal and average) intersect, the optimum production volume is reached, and the average total cost equals the marginal cost. Beyond this volume, the marginal cost curve is higher than the average total cost curve, thus achieving a region of no economies of scale. Thus, 100% economies of scale are achieved when the marginal cost curve equals the average total cost curve, i.e., at the optimal production scale, and both the coefficient of the function equals one and the elasticity of the cost function equals zero. This is achieved by approximately (16%) of cucumber farmers in Nineveh Governorate using surface irrigation, This means that these farms have achieved economies of scale (100%). The remaining farmers operating in smaller sizes should expand their farms until they reach the optimal size of 15.5 dunams, as they have the capacity to reduce their production costs to align with the optimal size identified in this study. Farms with areas larger than the optimal size, however, need to reduce their farms to the size that achieves the optimal production volume for this crop.

As for the achieved economies of scale ratio, the results showed that it increases with the increase in the size of production and reaches its maximum value at the optimal size of production (100%). However, with an increase in the size of production beyond the optimal size, the economies of scale ratio begins to decrease at increasing rates. The farms operating within the area of no economies of scale constituted (28%) of the percentage of farms for the cucumber crop in the study sample for flood irrigation. The percentage of farms operating within the area of economies of scale reached (72%), while the percentage of farms operating within the area of economies of scale (100%) at optimal production reached (16%) for the cucumber crop in Nineveh Governorate according to the flood irrigation method.

**ABLE (3): Size categories of cucumber farmers using surface irrigation**

Production Level (kg/donum)	Number of Farmers	Contribution Percentage (%)	Yield Stage
3000	3	%12	Increasing Returns to Scale (or Increasing Stage of Production)
4000	3	%12	Increasing Returns to Scale (or Increasing Stage of Production)
5000	5	%20	Increasing Returns to Scale (or Increasing Stage of Production)
6000	3	%12	Increasing Returns to Scale (or Increasing Stage of Production)
<b>7262.443</b>	<b>4</b>	<b>%16</b>	Optimal Output Level (or Optimum Scale)
8000	3	%12	Decreasing Returns to Scale (or Decreasing Stage of Production)
9000	2	%8	(Decreasing Returns to Scale (or Decreasing Stage of Production)
10000	1	%4	Decreasing Returns to Scale (or Decreasing Stage of Production)
11000	1	%4	(Decreasing Returns to Scale (or Decreasing Stage of Production)
<b>Total</b>	<b>25</b>	<b>%100</b>	

Source: Calculated by the researcher based on the questionnaire form





**TABLE (4): Realized Scale Economies, Cost Elasticity, and Function Coefficient at the Observed Production Level for Cucumber Farmers under Surface Irrigation**

Achieved Production Level (kg/donum)	Expected Average Total Cost at Achieved Production Level (thousand IQD)	Expected Marginal Cost at Achieved Production Level (thousand IQD)	Function Coefficient	Average Cost Function Elasticity	Realized Scale Economies (%)	Returns to Scale
3000	358.225	352.573	1.016	- 0.019	34.3	Economies
4000	356.562	350.794	1.0172	- 0.013	61.5	Economies
5000	355.341	350.341	1.0152	- 0.010	81.5	Economies
6000	354.562	351.214	1.0101	- 0.004	94.2	Economies
7262.443	354.21	354.21	1	0.000	100	Economies
8000	354.33	356.938	0.993	0.012	98	Diseconomies
9000	354.877	361.789	0.981	0.025	89.1	Diseconomies
10000	355.866	367.966	0.967	0.040	73	Diseconomies
11000	357.297	375.469	0.952	0.057	50	Diseconomies

Source: Calculated by the researcher based on the questionnaire form, the estimated cost function, the marginal cost function, cost elasticity, and the function coefficient.

**2- Modern Irrigation Techniques (Drip Irrigation):**

The short-run total cost function for the cucumber crop using drip irrigation was estimated and was consistent with economic logic in terms of statistical, econometric and economic tests, as follows:

$$SRTC = 54812.013 + 93785.301Q - 6.531Q^2 + 0.00021401Q^3 - 0.0685AQ + 0.0395A^2$$

**TABLE (5): Short-run total cost function of cucumber crop**

Independent Variables	Estimated Parameters	Statistical Parameters
Q	93785.301 (2.942)	R <sup>2</sup> = 0.87
Q <sup>2</sup>	- 6.531 (- 2.766)	R <sup>2</sup> = 0.86
Q <sup>3</sup>	0.00021401 (3.001)	F = 95.271
AQ	- 0.0685 (-4.452)	D.W = 1.856
A <sup>2</sup>	0.0395 (3.783)	n = 75

Source: Calculated using Eviews 12 software based on questionnaire data

When writing the function in its implicit form, we get:

$$V = C - 93785.301Q + 6.531Q^2 - 0.00021401Q^3 + 0.0685AQ - 0.0395A^2$$

Taking its first partial derivative with respect to the cultivated area (A) and setting it equal to zero, we obtain:

$$\frac{\partial V}{\partial A} = 0.0685Q - 0.079 A = 0$$

$$A = 0.867 Q$$



By substituting the value of A into the original function and summing the terms of  $Q^2$ , we obtain the long-run cost function for drip-irrigated cucumber crop:

$$LRTC = 93785.301 Q - 6.5607 Q^2 + 0.00021401 Q^3$$

Long-run cost function for drip-irrigated cucumber crop

### Statistical Analysis

After verifying the economic validity of the estimated parameters of the cucumber production model under drip irrigation, it was observed that the estimated coefficients were consistent with economic theory in terms of expected signs. Subsequently, statistical evaluation was conducted. The estimated parameters were found to be statistically significant, as indicated by the t-test, confirming the individual significance of the coefficients. In addition, the F-test confirmed the overall significance of the model at the 5% level. The coefficient of determination ( $R^2$ ) was found to be 87%, indicating that 87% of the variation in total cucumber output is explained by the independent variables included in the model, while the remaining 13% is attributed to other factors not included in the estimated specification.

### Econometric Analysis

To ensure the validity of the model for explaining the studied phenomenon, several econometric diagnostic tests were conducted. Regarding autocorrelation, the Durbin–Watson statistic ( $DW = 1.856$ ) indicated that the model is free from first-order autocorrelation, as the value falls within the acceptance region ( $1.77 < DW < 2.23$ ), satisfying the condition  $du < DW < 4 - du$ . Accordingly, it can be concluded that there is no evidence of positive or negative first-order serial correlation in the disturbance term.

With respect to multicollinearity, the model was found to satisfy the assumption of no severe multicollinearity among independent variables. Although polynomial terms such as  $Q^2$  and  $Q^3$  are algebraically related to  $Q$ , the functional form remains nonlinear, which reduces concerns regarding perfect linear dependence among regressors within the econometric specification.

To examine heteroskedasticity, the Park test was applied, which involves regressing the logarithm of squared residuals on the logarithm of output, using the following specification:

$$\log(e_i^2) = a + b \log(Q_i)$$

The estimated auxiliary regression for cucumber production under drip irrigation was as follows:

$$\log(e_i^2) = 8.351 + 0.193 \log(Q_i)$$

$$t = (0.715) (0.200)$$

$$R^2 = 0.231, F = 0.662, DW = 1.844$$

The results indicate that the estimated function is not statistically significant at the 5% level based on the F-test, and the t-statistics of the slope coefficient are lower than the critical t-values. Accordingly, the null hypothesis of homoskedasticity cannot be rejected, implying that there is no heteroskedasticity problem in the model.

### Economic Analysis

The economic analysis focuses on the practical application of the long-run cost function, particularly in estimating optimal production levels and cultivated areas for cucumber under drip irrigation. This includes the derivation of total cost, marginal cost, cost elasticity, and function parameters, which are used to determine economically optimal production scales and improve resource allocation efficiency.

### Determining the Optimal Cost-Economy (ECO) Size for Cucumber Production Using Drip Irrigation

To calculate the optimal size that minimizes costs (economy of scale) in cucumber production, it is first necessary to find the Long Run Average Total Cost (LRATC) equation. Since all production costs are variable costs in the long run,





the LRATC equation was derived from the total cost equation by dividing the latter by the output size (Q). The LRATC equation is as follows:

$$LRATC = 93785.301 - 6.5607 Q + 0.00021401 Q^2$$

In order to determine the optimal production volume that minimizes costs, the first necessary condition for minimizing the cost function must be applied, which is to take the first derivative of the average total cost function with respect to output and set it equal to zero, and then solve the equation with respect to Q, to obtain:

$$\frac{\partial LRATC}{\partial Q} = -6.5607 + 0.0004228 Q = 0$$

$$Q = 15517.265 \text{ kg/don}$$

$$Q = 15.517 \text{ Ton}$$

Optimal production size that minimizes costs and maximizes profits for drip-irrigated cucumber crop in Nineveh Governorate.

**Determining the optimal areas for cucumber cultivation using drip irrigation:**

To obtain the optimal areas planted with cucumbers in Nineveh Governorate, we substitute the value of Q for each crop into the value of A, obtaining:

$$A = 0.867 Q$$

$$A = 0.867 (15.517) = 13.453 \text{ don}$$

This is the optimal area that can be cultivated by cucumber farmers to obtain the optimal size of production that minimizes the average long-term cost and achieves the best long-term net income (maximum profit).

**TABLE (6): Actual and Optimal Production Levels and Cultivated Areas of Cucumber in Nineveh Governorate, 2025**

Crop	Actual Area (donum)	Optimal Area (donum)	Efficiency %	Actual Output (tons)	Optimal Output (tons)	Efficiency %
Cucumber	9.093	13.453	67.5	10.106	15.517	65.1

Source: Calculated by the researcher based on questionnaire data

Table (6) shows that the optimal sizes of the cultivated areas, amounting to (13,453) dunams for the cucumber crop in Nineveh Governorate, exceed the actual sizes of the cultivated areas with the same crop. Therefore, cucumber farmers must expand their areas by (4,36) dunams. Also, the optimal sizes of production came in rates that exceeded the actual rates for the aforementioned crop, as the optimal sizes of production reached (15,517) tons. Since the optimal sizes of production exceed the actual sizes, the farmers of the crop sample in the study must increase their production of this crop by (5,411) tons.

**Realized Scale Economies and Cost Elasticities for Cucumber under Drip Irrigation (Study Sample)**

According to economic theory, production levels below the optimal level achieve increasing rates of economies of scale, and upon reaching the optimal production level, a stable scale is achieved. However, production levels above the optimal level achieve decreasing rates, resulting in no economies of scale. This can be quantified according to the previous economies of scale formula:

Table (7, 8) shows that after the optimal production level, the average total cost begins to rise as the output volume increases, and then it continues to rise as production continues to expand. This is because economies of scale increase as the average total cost curve decreases until the economies of scale reach (100%), which is the stage of (stable yield) at the optimal production volume. At this stage, there is the (stage of increasing yield), in which the average total cost curve



decreases as the farm size expands, achieving increasing rates of economies of scale, Economies of scale occur due to two factors: one is the expansion of specialization and division of farm work, and the other is the increased possibility of using modern methods in agricultural production. This leads to a reduction in the average unit costs of output. However, when the farm size continues to increase, economies of scale appear, and consequently, the average total cost curve rises after the optimal size of production. This stage of production is called the stage of diminishing returns.

The results showed that the elasticity of the cost function is negative at production levels below optimum, indicating an inverse relationship between output and average cost. This means that average total cost decreases as output increases. Conversely, the elasticity of the cost function is positive at production levels above optimum, reinforcing the direct relationship between output and average cost at production levels above optimum. In other words, average total cost increases as output increases above optimum.

The coefficient of the function showed that its value is positive, greater than one, for production levels below optimum. Its value increases with increasing production volume, meaning that the rate of increase in production volume exceeds the rate of increase in costs, which is characteristic of the first stage of production (the stage of increasing returns). Knowing the marginal cost allows us to infer the achieved economies of scale. In the region of economies of scale, the marginal cost function is below the average total cost function. When the two cost curves (marginal and average) intersect, the optimal production volume is reached, and the average total cost equals the marginal cost. Beyond this volume, the marginal cost curve is above the average total cost curve, thus achieving a region of no economies of scale. Thus, 100% economies of scale are achieved when the marginal cost curve equals the average total cost curve, i.e., at the optimal production scale, and both the coefficient of the function equals one and the elasticity of the cost function equals zero. This is achieved by approximately 15% of cucumber farmers in Nineveh Governorate using drip irrigation. This means that these farms have achieved 100% economies of scale. The remaining farmers operating in suboptimal scale categories should expand their production until they reach the optimal area of 13,453 dunams, as they have the capacity to reduce their production costs to align with the optimal scale identified in this study, Farms that are larger than the optimal area are required to reduce their farm areas to the area that achieves the optimal production volume for this crop.

As for the achieved economies of scale ratio, the results showed that it increases with the increase in the size of production and reaches its maximum value at the optimal size of production (100%). However, with the increase in the size of production beyond the optimal size, the ratio of economies of scale begins to decrease at increasing rates. The farms operating within the area of no economies of scale constituted (29%) of the percentage of farms for the cucumber crop in the study sample for drip irrigation. The percentage of farms operating within the area of economies of scale reached (71%), while the percentage of farms operating within the area of economies of scale (100%) at optimal production reached (15%) for the cucumber crop in Nineveh Governorate according to the drip irrigation method. according to the flood irrigation method.



TABLE (7): Size categories of cucumber farmers using Drip irrigation

Production Level (kg/donum)	Number of Farmers	Contribution Percentage (%)	Yield Stage
11000	8	%11	Increasing Returns to Scale (or Increasing Stage of Production)
12000	8	%11	Increasing Returns to Scale (or Increasing Stage of Production)
13000	10	%13	Increasing Returns to Scale (or Increasing Stage of Production)
14000	16	%21	Increasing Returns to Scale (or Increasing Stage of Production)
<b>15517.265</b>	<b>11</b>	<b>%15</b>	Optimal Output Level (or Optimum Scale)
16000	12	%16	Decreasing Returns to Scale (or Decreasing Stage of Production)
17000	6	%8	(Decreasing Returns to Scale (or Decreasing Stage of Production)
18000	3	%4	Decreasing Returns to Scale (or Decreasing Stage of Production)
19000	1	%1	(Decreasing Returns to Scale (or Decreasing Stage of Production)
<b>Total</b>	<b>75</b>	<b>%100</b>	

Source: Calculated by the researcher based on the questionnaire form

TABLE (8): Realized Scale Economies, Cost Elasticity, and Function Coefficient at the Observed Production Level for Cucumber Farmers under Drip Irrigation

Achieved Production Level (kg/donum)	Expected Average Total Cost at Achieved Production Level (thousand IQD)	Expected Marginal Cost at Achieved Production Level (thousand IQD)	Function Coefficient	Average Cost Function Elasticity	Realized Scale Economies (%)	Returns to Scale
11000	47512.811	27135.531	1.851	-0.379	34.057	Economies
12000	45874.341	28780.821	1.751	-0.316	61.061	Economies
13000	44663.891	31710.171	1.594	-0.227	81.0105	Economies
14000	43881.461	35923.581	1.410	-0.077	93.905	Economies
<b>15517.265</b>	<b>43511.687</b>	<b>44768.583</b>	<b>1</b>	<b>0.0</b>	<b>100</b>	<b>Economies</b>
16000	43600.661	48202.581	0.904	0.184	98.533	Diseconomies
17000	44102.291	56268.171	0.784	0.358	90.266	Diseconomies
18000	45031.941	65617.821	0.686	0.542	74.944	Diseconomies
19000	46389.611	76251.531	0.632	0.731	52.569	Diseconomies

Source: Calculated by the researcher based on the questionnaire form, the estimated cost function, the marginal cost function, cost elasticity, and the function coefficient.

## Conclusions

1. The results of the questionnaire and the quantitative analysis of the cost functions indicated that profits at the optimal production level for both surface irrigation and drip irrigation exceed those achieved at actual production levels, accompanied by a relative reduction in production costs. This implies that moving closer to the optimal



production scale enhances profit efficiency. The findings also revealed that modern irrigation systems (drip irrigation) outperform traditional surface irrigation in achieving higher profits and lower production costs, reflecting greater economic efficiency in resource utilization.

2. The estimation of returns to scale, based on the cubic cost function, showed that only 15% of drip irrigation farms achieved the level of economies of scale for cucumber production. In contrast, 71% of farms operate in the increasing returns stage (pre-economic efficiency stage), while 29% operate in the decreasing returns stage (post-efficiency stage). These results indicate that the majority of farms are still operating within the increasing returns region, suggesting significant potential for improving production efficiency by adjusting production levels toward the optimal scale.
3. Based on the optimal production levels derived in the study, drip irrigation systems exhibited higher optimal output levels compared to surface irrigation systems. This is attributed to reduced resource wastage, resulting from better control over water use, labor input, pesticide application, fertilizer usage, and other agricultural operations.

### Recommendations

1. It is recommended to direct cucumber production levels in Nineveh Governorate, under both surface and drip irrigation systems, toward the optimal production scales estimated in the study in order to reduce deviations from the economically efficient level, thereby lowering total production costs and increasing actual farm profitability.
2. It is recommended to expand the adoption of drip irrigation systems in farms still operating within the stage of increasing returns, based on the study findings which demonstrated the superiority of this irrigation system in improving production efficiency and reducing waste in water and agricultural input use, thereby enhancing the economic performance of production units.
3. It is recommended to implement applied agricultural extension programs based on the results of cost function analysis and farm classification according to efficiency levels, with the aim of transferring expertise from efficient farms to less efficient ones in a systematic manner, while focusing on reducing waste in key production inputs and improving the overall economic efficiency of cucumber production

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