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ESTIMATION OF THE OPTIMUM QUANTITIES OF YIELD AND RESOURCES USED IN WHEAT CULTIVATION UNDER SUPPLEMENTARY IRRIGATION SYSTEM

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ABSTRACT

Optimization is so important that it is found in many applications such as engineering, economics, and computer science. It mainly focuses on finding optimum values of resources in order to reach optimal levels of output. The facts of wheat production in Iraq showed that it is grown in large areas depending on the rains in the rainy areas with high risks due to the dependence of the production there on the climatic conditions in terms of the fluctuation of rain. In view of the availability of sprinklers and by virtue of the relative scarcity factor and the great importance of productive resources used in wheat cultivation, especially supplementary irrigation water, the research aimed to estimate the production functions of the wheat crop using the Generalized Maximum Entropy method in order to estimate the optimum quantities of resources and output for wheat farms under the supplementary irrigation system in Nineveh governorate, specifically in the areas almost guaranteed to rain. This was done by relying on field data for a stratified random sample amounting to 93 farms and according to the type of irrigation system using the cuckoo search algorithm. Production (∑βi) of the inputs is less than the correct one according to the irrigation systems (5, 10, 20, 30 hectare), respectively (0.981, 0.941, 0.999, 0.823). This means that the productive stage of the research sample farms is the second productive stage. The research sample was close to reach the point of profit maximization which was found to be 15920, 30299, 65298, 101739 Kg where comparing the actual average production of the sample with the level of the maximum profit according to types of irrigation system, respectively.
Keywords: Wheat, CSA, optimization, supplementary, rain-fed

Introduction

Optimization is one of the main and central topics that are concerned with entrepreneurs and society alike. It gained and took an important place in the literature of economic thinkers and analysts, because it focuses on analyzing and measuring the efficiency of using productive resources (source). Iraq ranks 31st in the world and represents 0.4% of global wheat production, and Nineveh Governorate in northern Iraq is the main producer of wheat, close to 21% of the total output (Ewaid *et al.*, 2019: 2). In recent years, irrigation of the wheat crop has become dependent on modern sprinkler irrigation systems to counter the variation in rainfall between seasons and its distribution during one season, which led to low and fluctuating yields of rain-fed wheat from year to year. Alleviating soil moisture stress during the critical growth stages of rain fed wheat can improve crop yields and stability through the application of supplemental irrigation.

Optimization means choosing the best solutions to an existing or hypothetical problem, which mathematically means finding the minimum or maximum value for a given function (Muhammad, 2017; Rao, 2009) using multiple factors in an algorithmic system that are developed mathematically (Yang and Deb, 2014). Economically, optimization is the achievement of the maximum level of production at the lowest cost (Al-Douri and Abd, 2007). It is either Constrained Optimization, which means minimizing or maximizing the objective function f (x) depending on the constraints. Or unconstrained optimization, in which the function is minimized or maximized without constraints (Muhammad, 2017).

Algorithms have been developed based on some successful characteristics of the biological system of some communities of organisms (Fister Jr. *et al.*, 2013), especially meta-heuristics based on swarm intelligence (Yang, 2013). The cuckoo search algorithm (CSA) (2009 by Xin- She Yang and Suash Deb) is one of the most recent and most efficient super-intuitive algorithms inspired by nature (Yang, 2014), for its applicability to solve problems in optimization (Sopa and Angkawisittpan, 2016). These algorithms have been used with success in the studies of the Integrated Water and Land Management Program (Oweis and Hachum, 2009). And engineering design (Yang and Deb, 2010). Al-Hamdani 2012 showed the possibility of using the CSA algorithm in estimating the long-term cost function and economics of optimum volume in sprinkler-irrigated wheat farms in desert lands. The cuckoo algorithm was also adopted to solve the problem of optimal production planning in Iran based on the target function with price restrictions to reach the lowest cost (Charegozi and Jahani, 2013). In the possibility of generating operating units of electric power and delivering them to the consumer at the lowest operational cost (Serapiao, 2013), in the development of the long-term cost function of wheat crops for the agricultural season in Wasit Governorate (Ahmed, 2015), as well as the function of wheat production by the sprinkler irrigation system in Salah al-Din Governorate (Abd and Al-Samarrai, 2017).

Ashutoshrath *et al*. (2017) used CSA to derive an optimal cropping pattern in the Hirakud region of India for a variety of crops, including the wheat crop, in order to arrive at the maximum profit crop pattern. (Yang *et al.*, 2018) also presented a multi-type CSA for global optimization, and the CSA was approved to find an optimal single irrigation system function to improve water use efficiency in the winter wheat basin in the North China Plain (Xu *et al.*, 2018). In view of the availability of sprinklers within the irrigation technology project and the shift from unsecured agriculture to secured agriculture, and the increasing demand for the wheat crop as it is a major food crop, the topic of research was conducted on this crop and the governorate of Nineveh was chosen in order to identify the reality of the use of productive resources (inputs) in wheat cultivation, and find The optimum quantities of resources needed to cultivate this crop under the supplementary irrigation system according to the area used in order to reach the optimum yield at the maximum, minimum and maximum profit point, Whereas, a deviation from the optimal level results in a waste of resources and an undesirable increase in costs, and consequently a decrease in the level of production and profitability, and a failure to achieve self-sufficiency in the wheat crop. Estimating the optimal quantities of output and economic resources will provide the necessary information for decision-makers to guide and direct farmers on the use of productive resources in the optimal quantities, especially supplementary irrigation water, and the importance of this in sustaining and increasing wheat production in Iraq. The research is based on a basic hypothesis that the research sample from wheat crop farms in the semi-assured areas under the supplementary irrigation system in Nineveh governorate achieved optimal levels of output and resources used in wheat cultivation at the point of global profit maximization at which the largest positive difference is achieved. Between revenues and total costs. Therefore, the research aimed at first estimating the production functions of the wheat crop using the generalized maximum entropy method (GME) and then estimating the optimal quantities of resources and output for wheat farms under the supplementary irrigation system and according to the type of irrigation system, whether it is fixed (20, 40) dunums or axial (80, 120) Dunam using the cuckoo research algorithm (CSA), and the research relied on achieving its objectives on linking two methods: the first: the descriptive analysis method based on the concepts of economic theory and theoretical studies related to the topic of optimization of economic output and resources, and the second: the method of quantitative analysis based on statistical, measurement and mathematical methods, including It is commensurate with achieving the objectives of research using programs (SAS, CSA).

Materials and Methods

In this study, the optimum quantities of yield and resources used in cultivating the wheat crop under the supplementary irrigation system were estimated. Cross-sectional data was used for a stratified random sample of wheat farms under supplementary irrigation systems in semi-rain-guaranteed areas in Nineveh governorate for the growing season (2018) by using a questionnaire form prepared according to the research goals.

The research included a sample consisting of 93 farms spread in the semi-secured areas, which constituted 34.4% of the study population. The inputs of wheat production after fixing the area were according to the irrigation system used were u1: amount of seeds used per unit area (kg), u2: total amount of irrigation water, including the amount of effective rainfall/total area (m^3), u3: amount of compound fertilizer/total area (kg), u4: amount of urea used (kg), u5: human labor/area (man/day), u6: machinery used (working hours), in addition to Z: quantity of wheat production under supplementary irrigation system/total area (kg).

Determining the model for estimating the optimal quantities of resources and output for wheat farms under the supplementary irrigation system:

The optimum quantities of resources and output for wheat farms under the supplementary irrigation system were estimated using the generalized maximum entropy method (GME) after estimating the production functions of wheat yield and according to the type of irrigation system used, whether it was fixed (20, 40) dunums or axial (80, 120 dunums). The double natural logarithm of the dependent variable (Z) and the independent variables (U1 → U6) were taken according to the multiple regression analysis and at a significant level of 5% to determine the relationship (in the double logarithmic formula) between the natural logarithm of production (Z) and the natural logarithms of production inputs according to the type of irrigation system used. The estimated production function was converted from its double logarithmic form to the nonlinear exponential form (natural form of the Cobb Dauglas function). These functions were used to find the optimal quantities of resources and output at the global output max and at the lowest point, using unconstrained optimization through the cuckoo search algorithm (CSA) and depending on the technical relationship between the input quantity and the quantity of wheat production under the supplementary irrigation system. The optimum quantities of resources and output were also found at the point of global profit maximization, taking into account input prices and output price when studying the technical relationship between the quantity of these inputs and the output of wheat under the supplementary irrigation system.

The CSA was used to find the amount of inputs at the point of profit maximization through the total input, the target point (profit maximization), and the limits of maximization or minimization of the estimated production function, and the profit maximization point (Kaveh *et al.*, 2012)

Results and Discussion

Estimation of production functions of wheat crop according to the type of irrigation system for the 2018 growing season using a generalized maximal entropy method

Results based on the 't' test indicated high significance of the estimated parameters of the wheat production functions. The value of the determination coefficient (R2) for each analysis of the irrigation systems (5, 10, 20 and 40 Hectare), respectively, indicating that 64%, 67%, 69% and 61% of the changes in the production are due to changes in the independent variables (inputs) included in the model while the rest 36%, 33%, 31% and 39% of the changes in production are due to factors or variables that are not Included in the model.

It is also evident that the sum of production elasticity (∑βi) where i = 1 → 6 of the inputs in the productive function is less than the integer one that 0.981, 0.941, 0.999 or 0.823 according to the four irrigation systems respectively. This means that the productive stage of the research sample farms is at the second productive stage of the diminishing returns law, and it is an efficient sample. the results showed a positive relationship between the productive resources in the model and the output (wheat crop).

Table 1 : Estimating production functions using double logarithmic formula for wheat according to the type of irrigation system using the Generalized Maximum Entropy method

Production function according to irrigation system	$\ddot{B}_0$	$\ddot{B}_1$	$\ddot{B}_2$	$\ddot{B}_3$	$\ddot{B}_4$	$\ddot{B}_5$	$\ddot{B}_6$	R^2	$\sum\ddot{B}_i$ $(B_1 \rightarrow B_6)$
Stationary irrigation system, 5 Hectare	2.355 (359.36)	0.299 (391.03)	0.311 (376.82)	0.074 (296.03)	0.206 (315.11)	0.019 (106.09)	0.072 (247.35)	0.646	0.981
Stationary irrigation system, 10 Hectare	2.773 (194.15)	0.460 (399.49)	0.292 (246.02)	0.015 (40.57)	0.091 (70.13)	0.028 (29.43)	0.055 (49.20)	0.670	0.941
Pivot irrigation system, 20 Hectare	3.042 (43.37)	0.025 (176.04)	0.438 (50.61)	0.130 (14.21)	0.026 (12.74)	0.148 (13.12)	0.232 (22.18)	0.691	0.999
Pivot irrigation system, 30 Hectare	5.490 (64.98)	0.043 (98.81)	0.168 (59.80)	0.191 (31.21)	0.017 (19.33)	0.029 (17.08)	0.375 (34.71)	0.610	0.823

*Numbers between the parenthesis indicating the t calculated value

Estimation of optimum resource and yield quantities for wheat farms under supplemental irrigation system using the Cuckoo Search Algorithm (CSA)

The following tables and figures show the optimal quantities of the productive input bundle and the level of production achieved at the maximum and minimum point of production and the maximum profit in addition to the arithmetic means of the amount of output and the actual inputs used by the sample farmers in addition to the revenues, total costs and net revenues (profits) according to the type of irrigation system used.

The results shown in Table (2) indicate the optimal quantities of the resource bundle (inputs) used in the cultivation of irrigated wheat (seeds, irrigation water, compound fertilizer, urea fertilizer, human labor, mechanical technology) after stabilizing the area under a fixed irrigation system of 5 hectares using unrestricted optimization at the point of maximizing output, with differences between upper and lower levels of inputs. The results (Figure 1) showed that if the sample farm wants to reach the maximum optimum level of production, it should increase production by 2907 Kg.

Table 2 : Function of wheat production under a stationary irrigation system (5 and 10 Hectares)

Production function according to irrigation system	**Values**	**Seeds Kg U1**	**Irrigation Water m^3 U2**	**Fertilizer NP (Kg) U3**	**Urea Fertilizer (Kg) U4**	**Human Labor Man/h U5**	**Machinery (working h) U6**	**Production (Kg) Z**	**Total Returns IQD TR**	**Total cost IQD TC**	**Profit IQD π**
Stationary irrigation system, 5 Hectare	optimal maximum quantity (max)	660	28300	1000	1195	8.4	22	16613	-	-	-
	Profit max	660	28300	941	1194	5.1	14.8	15920	8644568	2901370	5743198
	optimal minimum quantity (min)	500	25200	609	660	5	14	12058	-	-	-
	Average (actual sample quantity)	545	26018	780	824	6.9	17.4	13706	7442358	2525846	4916512
Stationary irrigation system, 10 Hectare	optimal maximum quantity (max)	1320	53391	1760	2400	16.7	40	31537	-	-	-
	Profit max	1320	53256	800	1817	16	39	30299	16452092	4891861	11560231
	optimal minimum quantity (min)	1040	50061	800	1082	11.4	27	24682	-	-	-
	Average (actual sample quantity)	1221	51845	1395	1997	14.8	35.3	29385	15956055	5194958	10761097

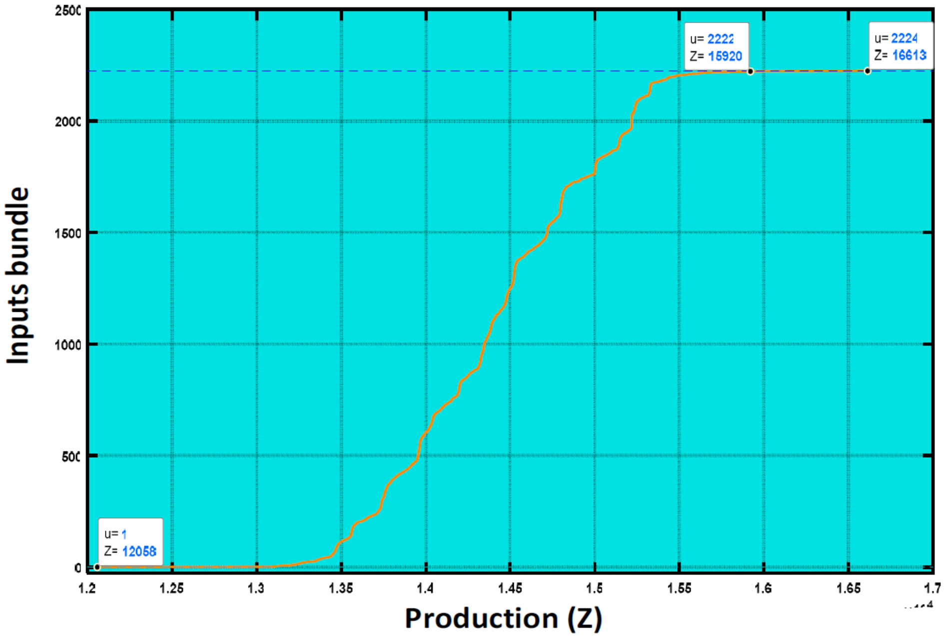

Fig. 1 : Function of wheat production under a constant irrigation system (5 Hectare)

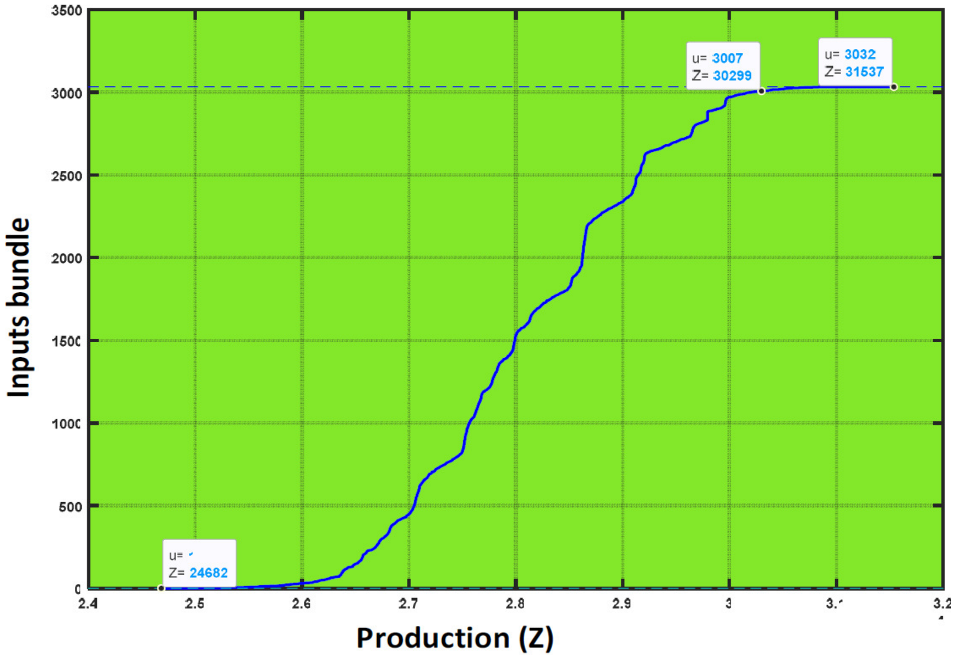

Fig. 2 : Function of wheat production under a constant irrigation system (10 Hectare)

But, if it wants to reduce production costs to the least possible level, the production needs to be reduced by 1648 Kg using the optimum quantities of bundles at each optimum level of production (Figure 1). Whereas, the level of production at the point of (Global Profit Max) using the restricted optimization in the case of the fixed irrigation system with an area of 10 hectares was (30299 kg) and the maximum profit was (11560231 dinars). So reaching the maximum production would require an increase in production by 2152 Kg, and the lowest possible costs would need to reduce production by 4703 Kg, but to reach the maximum profits, an increase in production would be required by 914 Kg (Figure 2).

The results (Table3) showed the optimal quantities of the resource after stabilizing the area under a fixed irrigation system of 20 and 30 hectares using unrestricted optimization at the point of maximizing output, with differences between upper and lower levels of inputs. Findings also showed (Figure 3 and 4) that Global Profit Max point, after fixing cultivation area under a pivotal irrigation system of 20 and 30 hectare, the total production using the restricted optimization was 65298 kg and 101739 Kg and level for the maximum profit of 25299676 and 39286685 IQD, respectively. In order to reduce costs to the lowest possible level in case of the 20 hectare farm under pivotal irrigation system, the farm production had to be reduced by 9,868 Kg, while maximizing production required an increase in production by 8,892 Kg, and the maximizing profits required an increase in production by 6,936 Kg using the optimal quantities of the bundle at each optimal level for production. Regarding the cultivation area under a pivotal irrigation system of 30 hectare, If the sample farmer wants to maximize production, he must increase his production by 12,183 Kg, but if he wants to reduce production costs to the lowest possible level, he must reduce her production by12,300 Kg, while maximizing profits requires an increase in production by 10679 Kg using the optimal quantities of the bundle at each optimum level of production.

Table 3 : Function of wheat production under pivotal irrigation system (20 and 30 Hectares)

Production function according to irrigation system	Values	Seeds Kg U1	Irrigation Water m^3 U2	Fertilizer NP (Kg) U3	Urea Fertilizer (Kg) U4	Human Labor Man/h U5	Machinery (working h) U6	Production (Kg) Z	Total Returns IQD TR	Total cost IQD TC	Profit IQD π
Stationary irrigation system, 5 Hectare	optimal maximum quantity (max)	2640	103642	4000	5100	33.4	74.3	67254	-	-	-
	Profit max	2469	103326	4000	1840	33.4	74.3	65298	35456595	10156919	25299676
	optimal minimum quantity (min)	2000	95837	1600	1840	22	53	48494	-	-	-
	Average (actual sample quantity)	2204	100934	2626	2809	27.7	64.8	58362	31690566	9366685	22323881
Stationary irrigation system, 10 Hectare	optimal maximum quantity (max)	4080	152543	6000	7714	48.2	111	103243	-	-	-
	Profit max	4080	152543	6000	4210	41.4	111	101739	55244184	15957499	39286685
	optimal minimum quantity (min)	3000	136653	3600	4080	31.4	81	78760	-	-	-
	Average (actual sample quantity)	3407	150576	4441	5214	39.6	96.8	91060	49445580	14867792	34577788

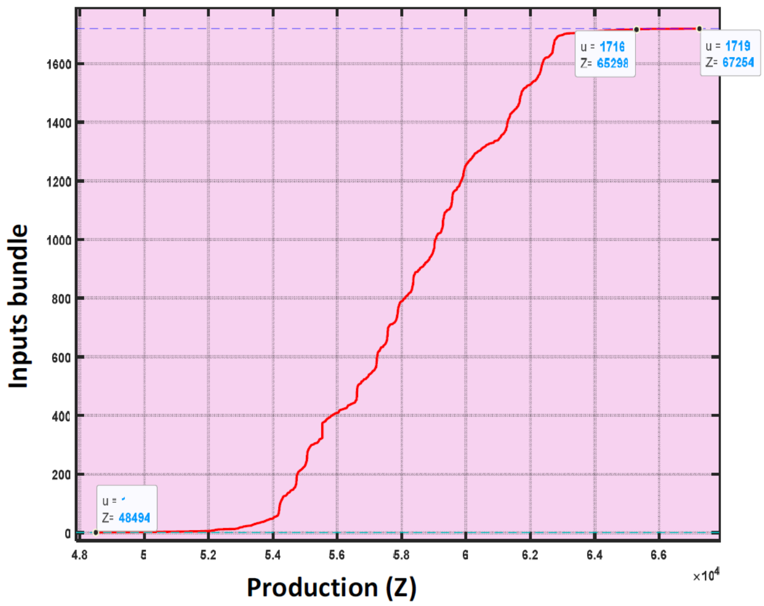

Fig. 3 : Function of wheat production under a constant irrigation system (20 Hectare)

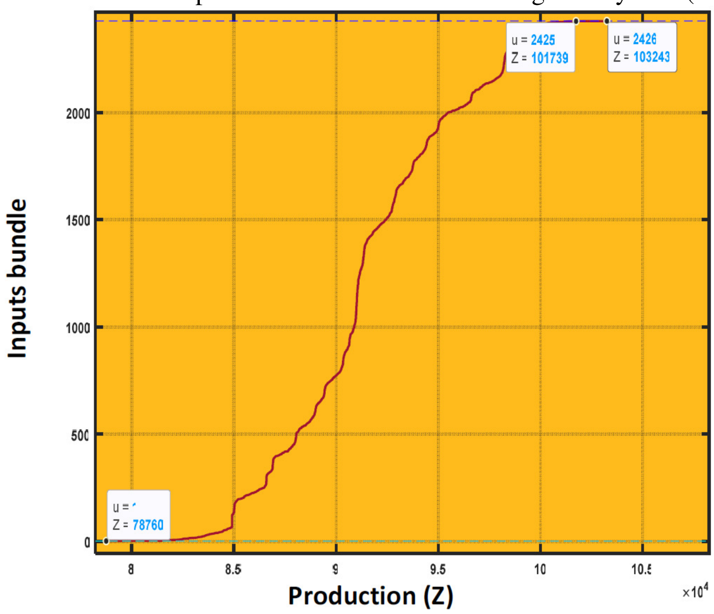

Fig. 4 : Function of wheat production under a constant irrigation system (30 Hectare)

The results indicate that the research sample from wheat farms of (93) farms did not reach the point of global profit maximization, at which the largest vertical distance between the total revenue line and the total cost curve is achieved, so that TR> TC is at its maximum. Thus, the sample farmer will be at the highest point on the Profit Curve and thus the total revenue slope is equal to the total cost slope, and this convergence means that the sample achieved profits and fell at a point located on the (expansion path). But the iso-cost line did not achieve contact with the highest iso-output curve possible, and this contradicts the research hypothesis that the sample from wheat farms in the semi-guaranteed rainy areas under the supplementary irrigation system in Nineveh Governorate achieved optimum levels of output and resources used in wheat cultivation at the point of profit maximization.

The results confirmed the efficiency of the cuckoo search algorithm (CSA) in finding the resource and output quantities at the maximum, minimum, and maximal points of profit through the total input. This is in agreement with previous studies of the possibility of using (CSA) as a method for solving constrained and unconstrained optimization problems, especially for polynomial nonlinear functions, within a short period of time. The CSA was used to determine the optimal crop cultivation pattern in India (Ashutoshrath *et al.*, 2017) and solve the production planning problem in Iran (Akbrazadeh and Shadkam, 2015) and solve nonlinear optimization problems (Yang *et al.*, 2018).

The four previous analysis results obtained using the CSA of the research sample (93 farms) under the supplementary irrigation system were linked according to the type of stationary irrigation system (5 and 10) hectare or pivotal system (20 and 30) hectare. The quantities of resources and production levels were divided by the total area (table 4) in order to determine

the quantity of inputs at the optimum, minimum and maximum points of profit and the output achieved at each combination of these points compared with the combination of inputs and the level of production achieved for area of one dunam (1/4 hectare).

Table 4 : Optimum quantities of resources and output for wheat farms research sample under supplementary irrigation system using the CSA measured for a dunam (1/4 hectare)

Production function according to irrigation system	Values	**Seeds Kg U1**	**Irrigation Water m^3 U2**	**Fertilizer NP (Kg) U3**	**Urea Fertilizer (Kg) U4**	**Human Labor Man/h U5**	**Machinery (working h) U6**	**Production (Kg) Z**	**Total Returns IQD TR**	**Total cost IQD TC**	**Profit IQD π**
Stationary irrigation system, 5 Hectare (20 dunam)	optimal maximum quantity (max)	33	1415	50	59.8	0.42	60	831	---	---	---
	Profit max	33	1415	47	59.7	0.26	44.4	796	432.228	145.069	287.159
	optimal minimum quantity (min)	25	1260	30.5	33	0.25	42	603	---	---	---
	Average (actual sample quantity)	27.3	1301	39	41.2	0.35	52.1	685	372.118	126.292	245.826
Stationary irrigation system, 10 Hectare (40 dunam)	optimal maximum quantity (max)	33	1335	44	60	0.418	60	788	---	---	---
	Profit max	33	1331	20	45.4	0.4	59	757	411.302	122.297	289.005
	optimal minimum quantity (min)	26	1252	20	27	0.285	41	617	---	---	---
	Average (actual sample quantity)	30.5	1296	35	49.9	0.37	53	735	398.901	129.874	269.027
Pivotal irrigation system, 20 Hectare (80 dunam)	optimal maximum quantity (max)	33	1296	50	63.7	0.418	56	841	---	---	---
	Profit max	30.8	1292	50	23	0.418	56	816	443.207	126.961	316.246
	optimal minimum quantity (min)	25	1198	20	23	0.275	40	606	---	---	---
	Average (actual sample quantity)	27.5	1262	32.8	35	0.346	49	730	396.132	117.084	279.048
Pivotal irrigation system, 30 Hectare (120 dunam)	optimal maximum quantity (max)	34	1271	50	64.3	0.402	56	860	---	---	---
	Profit max	34	1271	50	35	0.345	56	848	460.368	132.979	327.389
	optimal minimum quantity (min)	25	1139	30	34	0.262	41	656	---	---	---
	Average (actual sample quantity)	28.4	1255	37	43.5	0.33	48.4	759	412.046	123.898	288.148

It is evident from Table 4 that the maximum level of productivity per dunam was (860 kg), while the level of maximum productivity of profit reached (848 kg) in farms under a pivotal irrigation system 120 dunam. While the lowest optimum level of productivity was (603 kg), it was at farms under constant irrigation system of 20 dunam. If the goal of the research sample is to reach the lowest cost per dunam, and consequently for the total area, it is necessary to use the input package in the amount that achieves this at a fixed irrigation system of 20 dunam. Whereas, if the aim of the sample is to reach the maximum level of productivity and the maximum profits per dunam, and therefore for the total area, it is necessary to use a package of inputs in the amount that achieves this at a pivotal irrigation system of 120 dunam.

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