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Measuring the Economic Efficiency of Wheat Producers in Salah Al-Din Governorate for the Agricultural Season 2022-2023

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Abstract

This study examined the determinants of wheat output and technical efficiency of wheat farms in Salah al-Din Governorate during the 2023 agricultural season using stochastic frontier analysis. Primary data were collected through a purpose-designed questionnaire administered to a random sample of 150 farmers using fixed or center-pivot sprinkler irrigation systems. The fixed-sprinkler group comprised 60 farmers operating holdings of 10, 20, and 40 dunums, while the center-pivot group included 90 farmers with holdings of 60, 80, and 120 dunums. Estimated production coefficients were positive, statistically significant, and consistent with economic expectations. The maximum-likelihood log function yielded a positive value of 0.147, indicating that technical changes influence the stochastic component, agricultural output, and, consequently, technical efficiency. Analysis of water use showed that the most rational utilization occurred among farms in the 40-dunum fixed-sprinkler category and the 60-dunum center-pivot category. The corresponding potential for improving water-use efficiency was 19% and 18%, respectively. Younger farmers achieved higher technical efficiency than older farmers, reflecting their greater capacity to adopt contemporary agricultural technologies. The findings further indicate that wheat farmers can increase output through more economically efficient allocation of production resources. The study recommends intensifying agricultural extension and training activities, strengthening communication between farmers and research centers, and directing producers toward input combinations that minimize resource losses, reduce production costs, and increase returns. These measures can improve resource-use efficiency, strengthen farm-level production performance, and support higher and more economically efficient wheat productivity under both sprinkler irrigation systems in Salah al-Din Governorate.

Keywords

Technical Efficiency,
Irrigation Methods,
Frontier 4.1
Wheat Production; Stochastic
Frontier Analysis; Sprinkler
Irrigation;



Introduction

Wheat is at the center of Iraq's cereal crops and serves to feed people and livestock and is crucial to the food security of Salah al-Din Governorate (1). An increase in population and population growth puts wheat at the centre of these crops and agricultural practices and agricultural research to improve cultivation and use the available production capacity is needed. As of 2016,

Iraq faces a serious water restriction in the country's production of food and it also has a lack of available domestic sources to meet the demand of key commodities, especially cereals (2). Irrigation water, in the form of water supply and management, is a decisive factor for agriculture and therefore crop yield in the country (3). The wheat area needs to be developed and water conservation is important and modern irrigation technologies are one such technique (4). Fixed and center-pivot sprinklers are the key alternatives. Zhang et al. (5) pointed out the variety of sprinkler systems and Rovelto et al. (6) stated that their performance is dependent on the water, soil and climate in the environment to match the system.

Because rain-fed production is still unstable in several Arab countries, additional irrigation has been adopted to reduce the dependence on rainfall and production risk (7). Agricultural irrigation-water efficiency is also crucial to increasing Iraqi wheat production and meeting the country's food deficit (8).

Section One: Research Methodology

Research Objective

The study measures the economic efficiency of wheat farmers in Salah al-Din Governorate for the 2022-2023 season. It analyses how they use the economic resources available to grow wheat and whether the resources produce the highest possible output and return at the least cost. The study also estimates the wheat production function, identifies the inputs that are most efficient at maximizing its productivity and quantifies the technical, allocative and economic efficiency of the farms that have been sampled. The research also aims to explore whether a more efficient

input-cost combination can enhance production efficiency or lower total cost. It identifies the practices of farm inefficiency and suggests solutions to improve resource allocation, production efficiency and economic return for wheat farmers in the governorate.

Research Problem

The study of wheat farmers in Salah al-Din Governorate (2022-2023) is about how wheat farmers employed their productive resources. In this context, the question is whether those resources were used with technical, allocative and economic efficiency and whether a different allocation could actually increase the output or lower the production cost.

Importance of the Analysis

The economic efficiency of wheat farming in Iraq is important to assess as wheat is an important part of Iraq's agriculture and food industry and the governorate of Salah al-Din is one of them. The importance of this study is expressed in the following ways:

- a. Economic significance. Efficiency estimates show how successfully farmers convert available inputs into the greatest possible return at minimum cost. This evidence can support higher farm profitability and more economical use of agricultural resources.
- b. Production significance. The analysis isolates the inputs that influence wheat production and quantifies the role each of them plays in the production process. Farmers can use this information to make decisions about how much seed, fertilizer, pesticide, labor and equipment to put in place.
- c. Efficiency measurement. Technical, allocative and economic indicators give numerical measures of farm performance and show the difference between produced output and what can be produced given sufficient resources.

d. Practical relevance. The results can inform programs to improve land productivity, enhance the quality of farm operations and reduce potential losses.

Spatial and Temporal Scope of the Research

The spatial scope includes wheat-producing farms in Salah al-Din Governorate.

A. The primary information on cultivated area, output, input quantities, costs, prices and revenue was collected using a field questionnaire, according to the research objectives and economic analysis needs. A representative sample of wheat farmers in the districts and sub-districts of Salah al-Din Governorate was selected as long as the farmer population was large and reliable field information was available.

B. The time scale is the 2022-2023 agricultural season. The data for this season covers wheat output, production costs, input quantities and prices, and farm revenue. They were used to probe the relationship between the resources spent on wheat cultivation and the production. They also helped in the estimation of production costs, revenues and technical and allocative efficiency of each producer. Therefore, the study combines econometric estimation with economic analysis based on field data from 2022-2023 to find opportunities for better resource allocation and wheat production performance in Salah al-Din Governorate.

As a strategic crop, wheat is a key agricultural crop in Iraq as it is important for national food security as it is the main source of flour and bread production in Iraq. Production is widely distributed in much of the country, with a high percentage of wheat grown in northern and central governorates. Iraqi wheat farmers grow wheat in irrigated and rainfed environments, both in the United Arab Emirates and in the Middle East FAO (9). Changes in climate, water availability, cultivated and harvested area, input use, productivity and the economic and agricultural environment shaped this pattern.

Table (1): Wheat production in Iraq (2000-2022)

Years	Wheat production (Ton)
2000	1,040,000
2001	2,219,000
2002	2,590,000
2003	2,329,000
2004	1,832,000
2005	2,228,000
2006	2,286,000
2007	2,203,000
2008	1,255,000
2009	1,700,000
2010	2,749,000
2011	2,809,000
2012	3,062,000
2013	4,178,000
2014	5,055,000
2015	2,645,000
2016	3,053,000
2017	2,974,000
2018	2,178,000
2019	4,343,000
2020	6,238,000
2021	4,234,000
2022	2,765,000
Total	68,868,000
Arithmetic Mean	2,994,260.87
Maximum	6,238,000
Minimum	1,040,000

Ministry of Planning, Central Statistical Organization, Directorate of Agricultural Statistics

The statistics and Geographic Information Systems Agency records show that wheat output reached 3.053 million tons in 2016, weakened to 2.974 million tons in 2017 and to 2.178 million tons in 2018. The series then reversed direction and reached 4.343 million tons in 2019 and reached a record high of about 6.238 million tons in 2020. Output then fell to 4.234 million tons in 2021 and about 2.765 million tons in 2022. Production trends

The movement in wheat output can be interpreted through four consecutive periods:

The first stage (2000-2010): Output changed significantly from year to year in Iraq's economic and agricultural environment, climatic conditions and supply of water and other inputs. FAO (10) data indicate about 300,000 tons in 2000, almost 900,000 tons in 2001 and one million tons in 2002.

Phase Two (2011-2018): The annual variation was still present as rainfall, temperature, water supply and the area that was cultivated and harvested continued to vary. The official numbers showed 3.053 million tons in 2016 and the output dropped down to 2.178 million tons in 2018.

Phase Three (2019-2020): This was the largest expansion in the series. Wheat production increased from 4.343 million tons in 2019 to 6.238 million tons in 2020. The 2020 value is associated with better production conditions, a bigger harvested area and better yield during that season.

Phase Four (2021-2022): Production decreased from 4.234 million tons in 2021 to 2.765 million tons in 2022. Drought, water shortages and adverse climatic conditions were the primary reasons, especially in rain-fed areas. The reduction in irrigated area and the restrictions on agricultural water use were also factors. FAO (11), reports show drought-related damage in rain-fed areas, especially Nineveh Governorate, and that irrigated areas where crops are grown declined.

What Determines Wheat Production?

There are many factors that contribute to the variation in Iraqi wheat production from 2000-2022. Production depends on the amount and distribution of rainfall, temperature and drought, and on the country's policy on rain-fed farming. Meanwhile, the water scarcity is increasing as well, and the amount and quality of water to be irrigated is decreasing. Corn, seeds, pesticides and machinery determine productivity.

Field management and land access and the marketing of harvested wheat is also constrained by the government planning, procurement prices and input support which shape farm decisions. The 2000-2022 period indicates clear instability in the Iraqi wheat production. Years of exceptional output such as 2020 were followed by a sharp decline, such as 2022. This pattern indicates that production is not just about cultivated area but also about water management and resource efficiency, climate and yield performance.

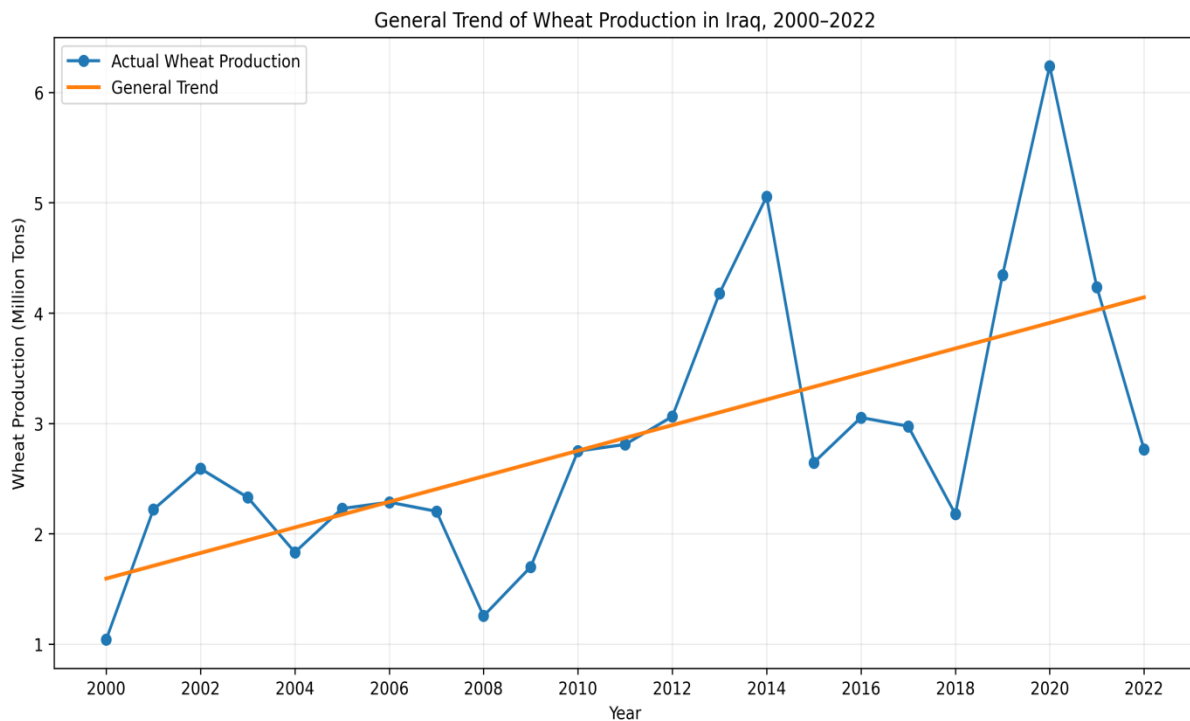


Figure (1) General trend of wheat crop production in Iraq for the period 2000-2022

The model used: Stochastic Frontier Production Function

The transcendental logarithmic (Translog) production function is a flexible specification when production depends on many inputs to the system. The more restrictive models (Cobb-Douglas and variable-elasticity-of-substitution) may not account for all the interactions that occur when more than two inputs contribute to the production process. Translog is a good solution to this problem, allowing us to test separability, substitution, symmetry and economies of scale.

We chose Stochastic Frontier Analysis (SFA) with a Translog model for our samples since the farms are quite heterogeneous and can operate below the production frontier. The method describes the output from the input and separates the disturbance into a symmetric random noise and a one-sided inefficiency part. Meeusen and Van den Broeck and, independently, Aigner, Lovell and Schmidt introduced the early cross-sectional frontier formulation. Unlike conventional error specifications, SFA does not assign every

unexplained deviation to random noise; it attributes part of that deviation to technical inefficiency. In the present application, the Translog stochastic frontier is used to estimate farm-level technical efficiency and to evaluate the contribution of the principal inputs employed by wheat farmers who use supplementary irrigation.

Frontier 4.1 was employed for parameter estimation and the calculation of technical-efficiency scores. Following Herrero and Pascoe (12), estimation proceeds through three stages. The Translog frontier adopted in this study is expressed as follows:

$$Y_{it} = \exp(B \ln x_{it} + V_{it} - U_{it})$$

$$\begin{aligned} \ln Y_i = & \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_{11} (\ln X_1)^2 \\ & + \beta_{22} (\ln X_2)^2 + \beta_{33} (\ln X_3)^2 + \beta_{44} (\ln X_4)^2 + \beta_{55} (\ln X_5)^2 + \beta_{66} (\ln X_6)^2 + \beta_{77} (\ln X_7)^2 + \beta_{1\rightarrow 7} \ln X_1 \ln X_2 \\ & + \beta_{1\rightarrow 6} \ln X_1 \ln X_3 + \beta_{1\rightarrow 5} \ln X_1 \ln X_4 + \beta_{1\rightarrow 4} \ln X_1 \ln X_5 + \beta_{1\rightarrow 3} \ln X_1 \ln X_6 + \beta_{1\rightarrow 2} \ln X_1 \ln X_7 \\ & + \beta_{2\rightarrow 6} \ln X_2 \ln X_6 + \beta_{2\rightarrow 5} \ln X_2 \ln X_5 + \beta_{2\rightarrow 4} \ln X_2 \ln X_4 + \beta_{2\rightarrow 3} \ln X_2 \ln X_3 + \beta_{3\rightarrow 6} \ln X_3 \ln X_6 \\ & + \beta_{3\rightarrow 5} \ln X_3 \ln X_5 + \beta_{3\rightarrow 4} \ln X_3 \ln X_4 + \beta_{4\rightarrow 6} \ln X_4 \ln X_6 + \beta_{4\rightarrow 5} \ln X_4 \ln X_5 + \beta_{5\rightarrow 6} \ln X_5 \ln X_6 \\ & + (U_i + V_i) \end{aligned} \quad (13)$$

$$U_{it} = \delta z_{it} + w_{it}$$

In this specification:

Y denotes wheat output measured in tons.

β_0 : constant limit.

β denotes the vector of coefficients to be estimated.

X_{it} denotes the observed production inputs.

X_1 denotes cultivated area measured in dunums.

X_2 denotes the volume of pesticides measured in liters.

X_3 denotes the number of mechanized-work hours.

X_4 denotes the volume of irrigation water applied in cubic meters.

X_5 denotes the quantity of seed measured in kilograms.

X_6 denotes the amount of fertilizer measured in kilograms.

V_{it} captures shocks outside the farmer's control, including rainfall variation. It follows a normal distribution with zero mean and constant variance.

U_{it} is a non-negative term that measures technical inefficiency. It can follow an independent half-normal distribution or another one-sided distribution with a non-zero mean and variance.

Z_{it} represents the explanatory variables associated with technical inefficiency.

The technical-inefficiency equation is specified as follows:

$$U_{it} = D_0 + D_1 Z_{1i} + D_2 Z_{2i} + D_3 Z_{3i} + D_4 Z_{4i} \dots (14)$$

where:

D_1 - D_4 are the coefficients of the inefficiency model.

Z_1 - Z_4 denote the farm-management characteristics included in that model.

The stochastic frontier model treats wheat output as the dependent variable. Cultivated area, seed quantity,

mechanized-work hours, applied irrigation water, pesticides and fertilizers constitute the production inputs. Frontier 4.1 was selected for estimation. Ordinary Least Squares (OLS) is used only to obtain an initial linear estimate and cannot by itself recover the nonlinear frontier and its two error components. Corrected Ordinary Least Squares (COLS) then supplies adjusted starting values for the subsequent frontier estimation.

In the final stage, Maximum Likelihood (ML) jointly estimates the production-frontier coefficients, the parameters of the inefficiency equation and the variance components. The resulting Translog estimates describe the production technology under SFA. Economic theory assumes that a producer seeks the input combination that yields the desired output efficiently. On this basis:

$$Y_i^* = B_i X_i K + V_i \dots (1)$$

Y_i^* denotes frontier, or potential, output.

B_i denotes the coefficients requiring estimation.

$X_i K$ denotes the set of inputs used in production.

V_i denotes the random disturbance with variance δ^2 .

The disturbance also reflects measurement error and possible specification error (13).

In observed farm data, actual output y_i may fall below the frontier output y_i^* by the amount u_i . This shortfall measures production inefficiency because realized output does not attain the feasible frontier. The relationship between frontier and observed output is therefore written as:

$$y_i = y_i^* - u_i \dots (2)$$

$$y_i = B_i x_i k + v_i - u_i \dots (3)$$

$$y_i = B_i x_i k + e_i \dots (4)$$

$$v_i - u_i = e_i \dots (5)$$

V_i represents statistical noise arising from influences that farms cannot control, such as weather,

measurement error and other random shocks. The terms are assumed to be mutually independent, homogeneous and independent of u_i , with zero mean and constant variance. Thus, V_i follows $N(0, \delta^2 v)$ and can take any value over the real line ($-\infty \leq V_i \leq \infty$).

U_i measures the output loss attributable to technical inefficiency and is restricted to values greater than or equal to zero. It may follow an independent half-normal distribution with non-zero mean $N(\geq 0, \delta^2 u)$ or a truncated normal distribution with mean U_i and variance $\delta^2 u$. When U_i equals zero, the farm operates on the frontier and attains full technical efficiency. A positive value places the farm below the frontier. Substitution of Equation (2) into Equation (3) produces the stochastic frontier production function:

$$Y_i = f(X_i, B_i) + \exp(V_i - U_i) \dots \dots \dots (6)$$

Farm-level technical efficiency TE_i is obtained as the ratio of realized output to frontier output, as stated in Equations (7), (8) and (9).

$$TE_i = \frac{Y_i}{Y_i^*} \dots \dots \dots (7)$$

$$TE_i = \frac{f(x_i B_i) + \exp(v_i - u_i)}{f(x_i B_i) + \exp(v_i)} \dots \dots \dots (8)$$

$$TE_i = \exp(-u_i) \dots \dots \dots (9)$$

A wider gap between realized and frontier output indicates greater inefficiency and a lower technical-efficiency score (14).

The total disturbance variance is the sum of the two component variances:

$$\delta^2 = \delta^2 u + \delta^2 v \dots \dots \dots (10)$$

Gamma is obtained from the following variance ratio:

$$\frac{\delta^2 u}{\delta^2 u + \delta^2 v} \dots \dots \dots (11)$$

A gamma value approaching zero implies that random noise and measurement error explain nearly all deviations from the frontier. A value approaching one indicates that technical inefficiency is the dominant source. Technical inefficiency becomes relevant when

farms using comparable inputs achieve different output levels because of differences in economic, technological or social conditions. The inefficiency term can be related to these conditions through the following model:

$$U_i = \sigma_0 + \sigma_1 Z_1 + \sigma_n Z_n \dots \dots \dots (12)$$

U_i is the non-negative term that quantifies technical inefficiency in production or cost.

$\sigma_0, \sigma_1, \dots, \sigma_n$ are the coefficients of the variables associated with efficiency differences.

Section Three: Economic Analysis of Wheat Production and Cost Functions Using Supplementary Irrigation

This section has two parts. The first estimates the wheat production and cost functions through a stochastic frontier specification. The second evaluates the economic-efficiency indicators related to irrigation-water use.

Estimation Results of the Translog (TL) Production Function Using Stochastic Frontier Analysis (SFA)

The SFA production model specifies wheat output as the dependent variable. The explanatory inputs are cultivated area, seed quantity, human-labor hours, applied irrigation water, pesticides and fertilizers. The inefficiency equation includes farm-management characteristics represented by the farmer's education, household size and experience with supplementary irrigation.

Frontier 4.1 was used because it estimates stochastic production frontiers and generates individual technical-efficiency scores. Estimation began with Ordinary Least Squares (OLS) to obtain preliminary coefficients. These estimates alone are insufficient for the frontier model because the production specification is nonlinear and contains two distinct disturbance components.

Corrected Ordinary Least Squares (COLS) was then applied to obtain adjusted initial coefficients and locate the empirical production frontier. The third stage used Maximum Likelihood (ML) to estimate the frontier coefficients, inefficiency parameters and variance parameters more efficiently.

The Translog production frontier and its inefficiency equation were therefore estimated jointly within the SFA framework by Maximum Likelihood. Table (2) reports the resulting coefficients and their statistical measures.

Table (2): Maximum-Likelihood Estimates of the Translog (TL) Frontier and Inefficiency Model

Parameter	Cof.	st.	t-r.
Beta0	6.804636	0.82361	7.266774***
Beta1	0.805541	0.12109	7.801322***
Beta2	0.086425	0.07659	0.948974
Beta3	0.054235	0.03079	2.604608***
Beta4	0.072018	0.03358	2.89601***
Beta5	0.145124	0.10034	1.391987*
Beta6	0.04027	0.07001	0.55368
Beta7	0.061415	0.04725	1.395684*
TE EFFECTS MODEL (inefficiency)			
Delta0	-1.10253	1.1125	-0.92589
Delta1	-0.0398	0.04012	-1.17276**
Delta2	0.028346	0.06123	0.398795
Delta3	0.002998	0.01219	0.298918
Delta4	0.025241	0.01158	1.69818
Delta5	0.022104	0.02158	1.041214*
sigma-squared	0.051032	0.01498	2.528415***
Gamma	0.906518	0.07589	10.80564***
log likelihood function	0.147		

Source: Researcher's work using Frontier 4.1 program

*Significant at 10%, ***Significant at 1%, **Significant at 5%

The estimated coefficients can be interpreted as follows:

The coefficient of X1 confirms a positive association between cultivated area and wheat output. A 1% expansion in area is associated with a 0.805541% rise in production, which agrees with economic theory and reflects the importance of large holdings for center-pivot irrigation. The pesticide coefficient X2 is also positive at 0.086425%, although its small magnitude may reflect insufficient farmer knowledge and limited extension support for correct pesticide application. Human labor X3 has a positive elasticity of 0.054235%. Its relatively small contribution is

consistent with the mechanized character of wheat cultivation. Mechanized-work hours exert a significant positive effect, with an elasticity of 0.072018%, in agreement with the crop's dependence on agricultural equipment. The applied-water coefficient is positive at 0.145124%, demonstrating both the production value of water and the relevance of modern irrigation technologies. Seed quantity has the expected positive sign: a 1% increase in seed use is associated with a 0.04027% increase in output. Fertilizer use also has a positive coefficient of 0.061415%. These results

support stronger extension programs that help farmers select economically rational quantities of production inputs. Under the ML estimates, cultivated area, mechanized-work hours and human labor are significant at 1%, whereas applied water and fertilizer are significant at 10%.

The inefficiency specification follows the model proposed by Ziu and Hnaay (1994), which links farm inefficiency to the included explanatory characteristics as follows:

$$U_{it} = \Sigma Z_{it} + \delta Z_{it} + w_{it}$$

The estimated management effects produced the following results:

D1, which is household size, is negative and significant at 5% so larger households are associated with higher technical efficiency and lower inefficiency. D2 is positive but statistically insignificant; it means that farmers with less formal education could perform more efficiently due to the accumulated practical experience. The supplementary irrigation experience coefficient D3 is positive and insignificant; this could be due to the recent introduction of these technologies and the limited experience farmers have learned to use them. Age D4 is positive and significant. This indicates that efficiency will decrease with farmer age and younger farmers are more able to adapt to new production technologies.

D5 measures experience in wheat cultivation and is positive and significant at the 10% level. The estimated sign suggests that older or more experienced farmers are less efficient in any way because of the continued reliance on traditional

practices which limits their response to technological change. Sigma squared σ^2 is 0.051 and significant at 1%, which supports the composite error distribution assumed here. Gamma Γ is also significant at 1%, indicating that production inefficiency is the reason for the deviation from the frontier. The maximum likelihood log function is positive at 0.147, suggesting that technical change impacts the random component, output and technical efficiency.

Economic-efficiency measures for irrigation-water use on the sampled wheat farms

In this study, we evaluate irrigation water with fixed and center pivot sprinklers. The outputs per unit of water, volume of water per ton, water-use efficiency and monetary return per unit of water are reported. Table (3) provides the values from below with DEAP2.1.

1. Water-unit productivity (kg/m³) equals wheat output in kilograms divided by the corresponding water allocation in cubic meters.

2. Water requirement per ton (m³/kg) is obtained by dividing the volume of allocated water by the quantity of wheat produced.

3. Water-use efficiency expresses production relative to the volume of irrigation water applied (15) used this measure to represent water-use performance. It may also be defined as output or return divided by the water consumed to obtain that output (16). The measure was computed with DEAP2.1.

4. Economic return per water unit (dinar/m³) is calculated by dividing total return per dunum (dinar/dunum) by total water use per dunum (m³/dunum).

Table (3): Economic-Efficiency Indicators for Irrigation-Water Use

*Economic return per water unit dinars/m ³	**Water use efficiency	*Water requirement per ton m ³	*Water unit productivity kg/m ³	Holding categories (dunum)
2405	0.77	2231	0.4132	10
2388	0.79	2316	0.4371	20
2309	0.80	2325	0.4365	40
2560	0.85	2217	0.4827	60
26324	0.81	2221	0.4555	80
2527	0.83	2273	0.4769	120

Source: Researcher's work based on the mentioned laws *and using the DEAP program

Table (3) shows limited variation in water productivity across the fixed and center-pivot systems. The 60-dunum category records the largest output per unit of water at 0.4827 kg/m³, followed by the 120-dunum category at 0.4769 kg/m³. The 120-dunum farms record a water requirement of 2273 m³ per ton. With respect to overall water-use efficiency, the highest value occurs for the 80-dunum group, whereas the 10-dunum group records the lowest value.

The estimates also show a great excess amount of water use, which indicates that wheat has a technical difference between the irrigation quantity required by wheat and the water actually supplied. The biggest economic return per unit of water is in the 80-dunum category, at 26,324 dinars/m³. The smallest return is 2,309 dinars/m³ for the 40-dunum category.

The irrigation indicators show that adding more water does not necessarily increase the wheat output or farm returns. Performance also depends on the skill to use fixed and center pivot systems and the farmers' ability to adapt irrigation to crop requirements. For the water loss in the sample, a number of factors are involved. Soil properties affect the water requirement of each dunum and climate and crop conditions also affect the right amount of irrigation. Water quality is a challenge because many farms in Salah al-Din Governorate have wells. Salts and mineral deposits in well water can reduce application efficiency and obstruct sprinkler outlets. Low yield lowers the efficiency value calculated because output enters directly into the indicator. Lastly, the inappropriate operation of fixed and center pivot systems and the poor farmer understanding of wheat-irrigation requirements are contributing to the low water-use efficiency found in the sample.

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