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ANALYSIS OF THE EFFICIENCY OF SPRINKLER IRRIGATION TECHNIQUES IN WHEAT PRODUCTION FARMS AND THEIR IMPACT ON PROFITS (A STUDY IN KIRKUK GOVERNORATE – IRAQ) FOR THE PRODUCTION SEASON

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Abstract. Wheat is one of the most important agricultural commodities worldwide, playing a significant role in food security and the agricultural economy. The increasing demand for wheat requires improvements in production efficiency and cost management, particularly through the adoption of modern irrigation technologies. This study aims to analyze production costs and economic efficiency in wheat farms using sprinkler irrigation in Kirkuk Governorate, Iraq, and to determine the optimal allocation of production inputs through the long-run cost function approach. The study uses data collected from 50 wheat farms to examine land ownership, water sources, irrigation systems, production inputs, agricultural operations, harvesting, and marketing activities. The findings indicate that 64% of farmers own their agricultural land, while 36% rent it. Regarding irrigation water sources, 56% of farmers use river water and 44% rely on well water. National electricity is the primary power source for sprinkler irrigation, used by 76% of farmers, while 24% depend on alternative sources such as generators and fuel. The average purchase price of sprinkler equipment, including pipes, reaches approximately 1,500,000 Iraqi dinars, representing a considerable initial investment. The analysis also shows that improved seeds are used by all farmers, while compound fertilizer and urea are used by 96% and 94% of farmers, respectively. Furthermore, all farmers rely on rented harvesting equipment, highlighting the additional costs associated with agricultural machinery. These findings suggest that irrigation equipment, energy consumption, fertilizers, harvesting, and transportation are important components of wheat production costs. Therefore, optimizing production inputs, improving irrigation management, and controlling operational expenses are necessary to enhance economic efficiency and increase farm profitability. The study provides an economic basis for evaluating production costs and supporting more efficient resource allocation in sprinkler-irrigated wheat farming.

Keywords: Wheat Production; Sprinkler Irrigation; Economic Efficiency.

Introduction:

In the world, wheat is secondly most economically important after maize since it is utilized in pasta and baked goods production. Wheat is a strategic commodity politically and a powerful food weapon by wheat producing and exporting nations. One of the most valuable cereal crops in the world is wheat and it is an essential component of food security of human societies, as well as using its by-products as livestock food.

Since the demand of wheat and the population growth is on the rise, as it is one of the main food crops, there has been the need to research on the barriers to the production of this valuable crop in order to achieve technical efficiency, with the hope that one will achieve economic efficiency. This therefore requires the incorporation of new scientific inventions that are able to generate more production at a lesser cost thereby resulting to greater economic efficiency than the traditional ones. Some of these inventions include modern irrigation methods that feature significantly in enhancing production and its quality. The role of sprinkler irrigation is especially important since it is a technically successful approach regarding the use of inputs and the volume of production.

Numerous economic studies have been conducted on wheat regarding production analysis, production costs, and the economics of scale, especially in Iraq. Study (1) examined the economics of wheat production under sprinkler irrigation compared to traditionally irrigated wheat farms through a long-run cost function analysis, including some local varieties in Salahuddin Governorate – Iraq. Study (3) analyzed the use of a bundle of technical factors in the national program for wheat cultivation development in Iraq, focusing on the long-run production and cost functions for wheat varieties (Bura, Rasheed, Abu Ghraib, Iba 99). This study conducted an economic analysis of the use of agricultural technologies in wheat farms, including improved seeds, micronutrients, fertilized seedbeds, and enhanced fertilizers, in Diyala Governorate – Iraq.

Study (2) The wheat production efficiency under irrigation systems has been analyzed using frontier analysis. The researchers used an economic approach of transcendental production function for wheat farms in Salahuddin Governorate – Iraq comparing the center pivot sprinkler irrigation with fixed sprinkler systems to analyze the economic efficiency of using modern irrigation techniques in wheat farms in the study area. Study (4) concentrated on the understanding of the technical factors influence on the productivity development of wheat in Egypt. The researcher found that the production of wheat increased from 3,300kg/ha to 6,500kg/ha in Egypt due to adopting the above methods..

This illustrates a gap between the level of technologies applied in wheat production farms and the costs incurred. This means the technologies are not being used optimally or there is a wrong investment of the invested money in the wheat farms. Thus, production costs will be analysed to obtain conclusions that support the hypothesis of this research.

Research Problem:

The problems of wheat production farms using modern irrigation techniques can be summarized in their most important aspect: the high production costs, particularly fixed costs, including the purchase price of irrigation sprinklers, which are the primary factor in implementing modern irrigation techniques. Therefore, the research problem is defined as the high production costs of sprinkler-irrigated farms, leading to low realized returns. This indicates a lack of technical efficiency in production and economic efficiency in production costs.

Research Hypothesis:
Economic reality indicates high production costs and low returns for wheat production farms using sprinkler irrigation techniques. Therefore, economic efficiency in production costs in these farms can be achieved by optimally allocating the main production inputs.

Research Objective:
The research aims to study the current state of wheat production costs in Kirkuk Governorate for farms using sprinkler irrigation techniques, conduct an economic analysis of these farms, and then determine the optimal levels of the main production inputs using the traditional economic analysis method of the long-run cost function.

Theoretical Framework:
Technological change is the change that arises as a direct effect of changes in knowledge. It is measured by the variation in output per unit of land, labor, or capital allocated over a specific period. Technological change is considered non-constant because scientific progress is not of fixed magnitude. Technical change achieves a quantitative leap in realized production, as the results of previous studies have shown a positive effect on production quantity in farms irrigated using modern irrigation techniques. This encourages horizontal expansion of production by increasing the cultivated area, since expanding the farm area makes all production inputs, such as capital and other elements, adjustable. Therefore, the analysis is conducted over the long run.

Based on this, the long-run cost function can be derived from the short-run cost function by replacing the fixed cost (b0) with the variable farm size (A) as follows: (1)

$$LRTC = b_1Q - b_2Q^2 + b_3Q^3 - b_4\,QA + b_5A^2 + Ui \quad \ldots\ldots(1)$$

By expressing equation (1) in its implicit form, since the Long-Run Total Cost (LRTC) is an implicit function of Q and A:

$$\mathrm{V} = \mathrm{LRTC} - b_1Q + b_2Q^2 - b_3Q^3 + b_4QA - b_5Q^2 - Ui = 0 \quad \ldots\ldots(2)$$

The optimal farm size is found by taking the first partial derivative with respect to the variable (A) and setting it equal to zero:

$$A = \frac{\partial V}{\partial \mathrm{A}} = 0 \quad \ldots\ldots(3)$$

$$\frac{\partial V}{\partial \mathrm{A}} = b_4Q - 2b_5A = 0 \quad \ldots\ldots(4)$$

$$A = \left(\frac{\mathrm{b}_4}{2\mathrm{b}_5}\right)(\mathrm{Q}) \quad \ldots\ldots(5)$$

Where (A) is expressed in terms of output (Q):
By substituting the value of (A) into the original function, the long-run cost function is obtained:

$$\mathrm{LRTC} = b_1Q - b_2Q^2 + b_3Q^3 - b_4Q\left(\frac{\mathrm{b}_4}{2\mathrm{b}_5}Q\right) + b_5\left(\frac{\mathrm{b}_4Q}{2\mathrm{b}_5}\right)^2 + Ui \quad \ldots\ldots(6)$$

$$= b_1Q - b_2Q^2 + b_3Q^3 - \frac{b_4^2\,Q^2}{2b_5} + \frac{b_5\,b_4^2\,Q^2}{4b_5^2} \quad \ldots\ldots(7)$$

$$= b_1Q - b_2Q^2 + b_3Q^3 - \frac{b_4^2\,Q^2}{2b_5} + \frac{b_4^2\,Q^2}{4b_5} \quad \ldots\ldots(8)$$

$$= b_1Q - b_2Q^2 + b_3Q^3 - \left(\frac{1}{2}\right)\frac{b_4^2\,Q^2}{b_5} + \left(\frac{1}{4}\right)\frac{b_4^2\,Q^2}{b_5} \quad \ldots\ldots(9)$$

$$= b_1Q - b_2Q^2 + b_3Q^3 - \left(\frac{1}{4}\right)\frac{b_4^2}{b_5}Q^2 \quad \ldots\ldots(10)$$

We obtain: (Y_2) by combining the terms.

$$= b_1Q - b_2Q^2 + \left(\frac{1}{4}\right)\frac{b_4^2}{b_5}Q^2 + b_3Q^3 \quad \ldots\ldots(11)$$

$$= b_1Q - \left(b_2 - \left(\frac{1}{4}\right)\frac{b_4^2}{b_5}\right)Q^2 + b_3Q^3 \quad \ldots\ldots(12)$$

Thus, the long-run total cost function is formulated as follows: (1)

$\mathrm{LRTC} = b_1Q - b_2Q^2 + b_3Q^3$ The long-run cost function

The long-run average cost (LRAC) is found by:

$$\mathrm{LRATC} = \frac{\mathrm{LRTC}}{Q}$$

Then, by taking the partial derivative with respect to output (Q), we obtain:

$$Q = \frac{\partial \mathrm{LRATC}}{\partial \mathrm{Q}} = -b_2 + 2b_3Q = 0$$

$$\therefore Q = \frac{b_2}{2b_3}$$

This represents the optimal output level that should be achieved to minimize costs and maximize profits.

Practical Framework

Discussion of Statistical Results

Table 1. Type of Agricultural Land Ownership

Type of Ownership	Number of Farmers	Percentage (%)
Owned	32	64%
Rented	18	36%
Total	**50**	**100%**

Table **Explanation:**
The table above shows the type of agricultural land ownership within the study sample, which consists of 50 farms in Kirkuk Governorate.

It is also evident that most farmers are owners of their farm land with 64 percent of them owning the land and 36 % of the sample renting the land.

The distribution shows a large share of farmers can be more inclined to invest in modern irrigation methods, e.g. sprinkler irrigation, because of the ownership of land, which guarantees the long-term pay-off of such investments.

Conversely, farmers on rental lands might be reluctant to embrace new technologies due to uncertainties of the long-term returns or due to the short life of the lease agreement between them and the landlord.

Table 2. Type of Irrigation Water Used in Wheat Farms

Type of Water	Number of Farmers	Percentage (%)
River Water	28	56%
Well Water	22	44%
Total	**50**	**100%**

Table **Explanation:**
The table shows the types of irrigation water sources used by farmers within the study sample.

The findings show that majority of the farmers (56 percent) use river water as their primary irrigation source and 44 percent use the well water.

This indicates the heterogeneity of the water sources in Kirkuk Governorate, the variability of geographical and environmental conditions in the different areas.

The nature of water source can be crucial in effectiveness of sprinkler irrigation methods with river water being more plentiful, yet less predictable, and well water being more predictable, yet more expensive to operate.

Table 3. Irrigation Methods

Variable	Typical Value	Percentage / Frequency	Notes
Sprinkler Coverage Area (Dunam)	60 - 120	—	Varies by Sprinkler Type
Average Sprinkler Purchase Price (IQD)	1,500,000	—	Including Pipes
Sprinkler Power Source	National Electricity	38 Farmers (76%)	The rest use generators or fuel
Alternative Power Source (Fuel/Generator)	—	12 Farmers (24%)	They use it in case of a power outage.

Table Explanation:

• Most farmers (76) use national electricity as the primary source of power to drive the agricultural sprinkler, and thus, the reliability of the electricity supply becomes an important issue of irrigation efficiency.
• A minority of farmers (24%) depend on alternative power sources such as generators or fuel. The mean price of a sprinkler plus its accessories is about 1,500,000 Iraqi Dinars, which is a relatively high price of investment.
• The area of sprinkler coverage is between 60 and 120 dunams, and the coverage is appropriate as it is between medium and large-scale production.

Table 4. Analytical Overview of Wheat Production Inputs for a Sample of 50 Farms in Kirkuk Governorate

Type of Input	Average per Dunam	Average Price (IQD)	Number of Users (Estimated)	Percentage (%)
Compound Fertilizer	50 kg	875,000 IQD / Ton	48	96%
Urea Fertilizer	50 kg	600,000 IQD / Ton	47	94%
Wheat Seeds (Improved Local Variety)	1 Ready-to-Use Jar/Dunam	—	50	100%
Insecticide	1 Pack / 20 Dunams	Varies by Type	35	70%
Herbicide	1 Pack / 10 Dunams	—	42	84%
Seasonal Fuel Costs	—	Variable (Depending on Pumping)	50	100%
Oil and Filter Costs	—	15,000 IQD / Season	50	100%
Sprinkler Maintenance Costs	—	25,000 IQD / Season	38	76%
Land Rent Costs	—	400,000 IQD / Dunam	20	40%
Land Plowing Wages	—	25,000 IQD / Dunam	50	100%
Transportation and Delivery Costs	—	10,000 IQD / Dunam	50	100%
Other Additional Costs	—	5,000 IQD / Dunam	30	60%

- All farmers use improved seeds and pay for plowing and transportation, indicating full reliance on professional farming practices.
- Compound fertilizer and urea are widely used (over 90%), highlighting the importance of chemical fertilization in improving production.
- Fuel, maintenance, and energy costs are present for all farmers, demonstrating the significance of agricultural equipment and its requirements.
- Rent represents a smaller proportion, as some farmers own their land (60%), which may affect overall profitability.
- The use of pesticides is slightly lower, reflecting differences in need or the ability to purchase them.

Table 5. Analytical Overview of Agricultural Operation Costs in Wheat Farms (Sample: 50 Farms – Kirkuk Governorate)

Agricultural Operation	Number of Work Hours (Per Dunam)	Cost (Per Dunam in IQD)	Number of Farmers Using	Percentage (%)
Plowing	Three hours.	10000	48	96%
Leveling and Adjusting	Three hours.	12500	50	100%
Fertilization	Eight hours.	20000	45	90%
Opening Irrigation Channels	—	—	25	50%
Sowing	Three hours.	12000	50	100%
Compound Fertilization	Three hours.	30000	47	94%
Urea fertilization.	Two hours	15000	44	88%
Control	Two hours	10000	49	98%
Irrigation	Seven hours	5000	50	100%
Other additional services	As needed	تختلف	20	40%

Table Explanation Agricultural Operations in the Cultivation of Wheat.

The following is an analysis of the major farming practices of farmers in the wheat growing season as shown in the table:

- The number of working hours per hectare for each operation
- The estimated cost per hectare according to the type of operation
- The number of farmers using each operation out of a sample of 50 farmers
- The percentage indicating the prevalence of each operation within the sample

✓ Table Content Analysis:

1. Plowing:

- It is carried out for approximately 3 hours
- It costs about 10,000 Dinars per hectare
- It is used by 96% of the sample, indicating that it is an essential operation for land preparation before planting

2. Leveling and Adjustment:

- It also lasts for 3 hours and costs 12,500 Dinars per hectare
- It is used by 100% of the farmers, indicating that it is essential for ensuring planting quality

3. Fertilization:

- It takes 8 hours, making it one of the longest operations
- It costs 20,000 Dinars per hectare and is used by 90% of the farmers

4. Opening Irrigation Channels:

- No clear data on hours or cost
- It is carried out by only 50% of the farmers, indicating that it depends on land characteristics or the availability of other irrigation methods

5. Sowing:

- A main operation, lasting 3 hours with a cost of 12,000 Dinars per hectare
- Used by all farmers (100%)

6. Compound Fertilization:

- Lasts 3 hours with a relatively high cost (30,000 Dinars)
- Used by 94% of the farmers, reflecting awareness of its importance for improving yield

7. Urea Fertilization:

- Takes 2 hours and costs 15,000 Dinars
- Used by 88% of the farmers, highlighting its role in wheat growth

8. Pest Control:

- A short operation (only 2 hours) with a cost of 10,000 Dinars
- Used by 98%, reflecting the prevalence of pests and the need for protection

9. Irrigation:

- A basic operation, lasting 7 hours with a cost of 5,000 Dinars
- Used by 100% of the sample

10. Other Additional Services:

- Such as maintenance, equipment repair, and others
- Varies according to need, used by only 40% of the farmers

General Conclusion:

- The most common operations are leveling, sowing, irrigation, and fertilization
- There is variation in the use of operations such as opening irrigation channels and other additional services, due to differences in land characteristics and equipment availability
- These data are very useful for calculating the total cost per hectare and identifying the operations that have the greatest impact on efficiency and profits

Table 6. Statistical Analysis Table for the Harvesting Process

Item	Frequency of (Number Farmers)	Percentage (%)	Notes
Type of Harvester: Rental	50	100%	All farmers rely on rented harvesters
Harvesting Cost per Hectare (25,000 Dinars)	50	100%	The cost is uniform among all farmers
Transport Cost to Initial Storage (50,000 Dinars)	47	94%	Most farmers use animal-drawn carts for transportation
Transport Cost to Warehouses (Nominal Price)	50	100%	The nominal price indicates the presence of subsidies or variation in distances

Results Analysis:

1. Total dependence on rented harvesters:

Means: farmers do not have their own equipment and this contributes to the cost of production and they are susceptible to the market fluctuations during peak seasons.

2. Homogenous cost of harvesting (25,000 Dinars per hectare):

Suggests that there is an agreed market price or a market rate that is determined by agricultural associations or supporting agencies.

3. Animal carts used to transport crops:

The ease of use and ubiquity of the method means that 94% of farmers use it to move their crops, but the method could lack capacity and cause delays during peak seasons.

4. The cost of transporting crops to warehouses at a nominal price:

This price is probably government subsidized or negotiated as part of the farmer support schemes.

Table 7. Marketing Activities Results

Category	Number of Workers	Sample Size	Percentage
Crop Bagging Operation	4	20	40%
Loading the Harvest onto Transport Trucks	3	15	30%
Unloading the Harvest at the Feed Processing Plant	3	10	20%
Transport Cost per Ton	-	5	10%

Statistical Analysis

1. Work Distribution:

An example: a sample of 50, bagging of the harvest, the largest part of the work, is done by 40 percent of the labor force. This is followed by loading the harvest (30%), and then unloading (20%).

2. Labor Wages:

Labor costs are allocated in the following way: The maximum costs are related to the loading and unloading operations, and both of them cost 15,000 Dinars. This highlights the importance of these operations in the supply chain.

3. Transport Costs:

Don't see that, 10 percent of the total operations are spent on transport costs, which means that they are not the biggest part of the marketing costs.

Table 8. Marketing Services at the Silo or Commercial Markets

Category	Quantity (Ton)	Sample Size	Percentage (%)
Quantity Marketed Before the Silo	50	30	60%
Quantity Marketed Reaching the Silo	19	20	40%

Discussion of Results

A. Quantity Sold P.B. Silo:

• 60% of the sample is marketed before reaching the silo. This means that most of the production is sold directly in the markets or exported immediately.

2. Quantity Sold to the Silo:

R = 40% of the sample is deposited to the silo. This can be an indication that there is a need to store temporarily until final marketing or to utilize silo facilities to enhance quality of storage.

3. Efficiency:

The fact that the marketing percentage is higher prior to the silo implies that there is a robust distribution channel that facilitates quick sales of products without necessarily having to store them over time.

4. Challenges:

• The volumes that get to the silo create logistical problems of storage and inventory control that can add up to marketing expenses.

Table 9. Final Marketing

Category	Amount (Dinars)	Sample Size	Percentage (%)
Waiting Period at the Silo	850	20	40%
Silo Storage Commission (per Ton)	125	15	30%
Quality Grade of the Marketed Product	1850	15	30%

Discussion of Results

1. Waiting Period at the Silo:

• Forty percent of the sample has a wait period at the silo which could cause delays in marketing activities and higher costs involved in the lost time.

2. Silo Storage Commission:

• Storage commission costs are incurred by 30% of the sample, which means that temporary storage is required to preserve the quality of products, or to prepare the marketing process.

3. Quality Grade of the Product Sold in the market:

• The sample size that gets the desired quality grade is 30 percent, which implies that certain marketing activities are effective in meeting the financial targets.

Table 10. Selling Prices

Category	Value (Dinars)	Sample Size	Percentage (%)
Selling Price per Ton to the Silo	850	25	50%
Selling Price per Ton to Commercial Markets	170	25	50%

Discussion of Results

1- Selling Price per Ton to the Silo:
• %50of the samples sell the ton to the silo at 850 Dinars. This can be an indicator that there is a stable market in silo storage and farmers will be able to receive a fixed price.
2- Commercial Price per Ton to sale:
• %50of the samples sell the ton in commercial markets at 170 Dinars. This is indicative of the multitude of channels open to farmers, where the choice of channels can be based on how quickly the sales can be made or based on the preference of the farmers.

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