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# ECONOMIC ANALYSIS OF THE IMPACT OF IRRIGATION METHOD AND FACTORS AFFECTING ITS ADOPTION IN WHEAT FARMS IN THE 2023-2024 SEASON: THE ANBAR GOVERNORATE AS A STUDY MODEL

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## Abstract

The importance of studying wheat crops comes from its vast planted areas in the world. In Iraq it has been characterized in recent years by increasing water scarcity, which requires rationalizing water consumption for agricultural use through proper irrigation management. Wheat crops can significantly affect the water balance and increase their ability to expand to other areas. This research aimed to study the effects of irrigation methods employed for the crop on its productivity and efficiency of water use. It examined the factors affecting the adoption of irrigation methods based on data from a sample of farmers in Anbar governorate. The study found that wheat productivity under the fixed sprinkler irrigation method reached 1042 kg/dunum, followed by the pivot sprinkler system at 996 kg/dunum. The sprinkler irrigation method recorded the highest fixed cost per ton of wheat. It was found that water use efficiency of the pivot sprinkler method was 81%, followed by the fixed sprinkler and traditional irrigation systems at 79% and 62%, respectively. Water unit productivity reached 0.758, 0.741, and 0.505 kg/m3 of water for the fixed, axial, and traditional irrigation methods, respectively. Wider planted areas and open spaces increased the likelihood of adopting the pivot over the fixed sprinkler metho.

**Keywords:** Irrigation method, Logistic regression, Analysis of variance, Water efficiency, Water productivity.

# تحليل اقتصادي لأثر طريقة الري والعوامل المؤثرة على تبنيها في مزارع القمح للموسم 2023-2024 (محافظة الانبار كأنموذج دراسي)

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**الخلاصة**

ان اهمية دراسة محصول القمح تأتي من اتساع المساحات المزروعة بالمحصول في العالم بشكل عام وكذلك في العراق الذي اتسم في السنوات الاخيرة بتزايد شحة المياه، مما يعني ان ترشيد استهلاك المياه في الاستخدام الزراعي يمكن ان تبدأ من ادارة ري محصول القمح الذي يمكن ان تؤثر بشكل مهم على الميزان المائي وتزيد من القدرة على التوسع الى مساحات اخرى ولذلك استهدف البحث معرفة تأثير طريقة ري محصول القمح على انتاجية وحدة المساحة وعلى معدلات التكاليف وكذلك كفاءة استخدام المياه، ودراسة العوامل التي تؤثر على تبني طريقة الري باستخدام بيانات عينة من مزارعي محافظة الانبار اذ تبين بان انتاجية القمح تحت الري بالرش الثابت بلغت 1042 كغم/دونم تلتها طريقة الري بالرش المحوري بإنتاجية 996 كغم/دونم. وسجلت طريقة الري بالرش اقل معدل تكلفة ثابتة لطن القمح. وتبين بان كفاءة استخدام المياه بطريقة الرش المحوري بلغت 81% تلتها طريقة الرش الثابت بكفاءة 79% بينما بلغت كفاءة استخدام المياه بالري التقليدي 62%. وانتاجية وحدة المياه بلغت 0.758 و 0.741 و0.505 كغم/متر مكعب ماء للري بالرش الثابت ثم المحوري والتقليدي على التوالي وتبين بان زيادة المساحة تزيد من احتمالية تبني الرش المحوري بينما تقلل من احتمال تبني الرش الثابت وان المساحات المفتوحة تشجع على تبني الرش المحوري. لذلك نوصي بمنع تفتت المساحات عن الحدود التي تسمح بتبني طرق الري الحديثة، وتقديم مرونة في ازالة الحدود المقيدة للاستثمار بطرق الري الحديثة.

**كلمات مفتاحية:** طريقة الري، الانحدار اللوجستي، تحليل التباين، كفاءة الري، انتاجية المياه.

## Introduction

Wheat is an economically important crop in Iraq, and is of strategic importance to Iraqi producers, consumers, and planners alike. Its importance to producers and agricultural planners stems from the vast area planted with the crop, as it represents the main food item among Iraqi consumers. With more than 40% of the total agricultural area planted with the crop it represents a key factor in the Iraqi water balance configuration. The amount of water required for wheat cultivation is affected by the irrigation method adopted, and wheat productivity per unit of water may vary among the different irrigation methods employed. The irrigation methods adopted, in turn, are dependent on the technical and economic characteristics of the farms and its owners.

Furthermore, the productivity per unit area of wheat and production costs may differ from one irrigation method to another (2).

The imbalance in Iraq's water balance in recent decades and the worsening water situations is evident from the decline in the per capita share of water from 5,000 m3 in 1980 to less than 1,000 m3 after 2020. This is mainly due to projects implemented by riparian countries with Iraq in the Tigris and Euphrates basins. In addition, the effects of climate change, and the attendant decline in rainfall rates in Iraq, have placed it in dire need of increasing water use efficiency and reducing waste through more efficient irrigation methods. Despite this, agricultural areas that rely on traditional irrigation methods still constitute a large percentage of the land planted with wheat in developing countries and Iraq in particular (12).

Water resources face significant challenges as its demand increases due to population growth and climate change. Improving water use efficiency has become critical to achieve sustainability and ensure food security. Improving water productivity is one of the key tools to achieve this goal. Therefore, this study examined the impact of the adopted irrigation methods on the unit area productivity of wheat and its average production cost which has been found to vary depending on the irrigation method employed. It also aimed to identify the factors influencing the adoption of a particular irrigation method by estimating a logistic regression to determine the impact of various factors on the farm and farmers on the irrigation method employed. It also aimed to measure unit water productivity and use efficiency according to the adopted irrigation methods.

## Materials and Methods

Randomly selected data from major farms were gathered from the agricultural division administrations in Anbar. The sample size was 141 farms of which 81 used the center-pivot irrigation system, 22 had fixed sprinklers, and 38 used conventional irrigation methods. The questionnaire distributed sought information on farm and individual characteristics, costs, production, and the amount of water consumed during the agricultural season. The data and information were analyzed using appropriate statistical methods, such as analysis of variance (ANOVA), to determine whether any factor or characteristic of the farm had an impact on the average cost of production per ton or productivity per unit area of the farm according to irrigation method. Water use efficiency was calculated based on irrigation method while the impact of specific characteristics on irrigation method adoption was measured using logistic regression. The dependent variable represented the adopted irrigation method, which is a nominal variable. The indicators were as follows:

Water Use Efficiency: Water use efficiency is a goal of water resources management. Unit water productivity indicates the production (agricultural crop or economic output) generated from a unit of water consumed and represents the efficiency of water use on the farm. Efficiency is calculated for each irrigation method. Water productivity was calculated using the following equation (18).

$$PW = \frac{Y}{ET}$$

where, PW: water productivity; Y: yield amount; ET: amount of water consumed.

Water use efficiency can be improved by increasing the percentage of useful water (2) and reducing losses by using efficient irrigation methods and improving water distribution in the field. The following formula was used to calculate the water use efficiency of the different irrigation methods (3) based on data provided by the farmers in the questionnaire (7).

$$WE = \frac{NW}{WU} * 100$$

where, WE is water-use efficiency, NW the amount of water required for the area, and WU the amount used.

Analysis of Variance: Measuring the effect of a factor or characteristic on farms depends on the production rate or cost rates. This is achieved by using an analysis of variance (ANOVA) and calculating the F-test to determine the extent of significant differences between factor levels on productivity and cost rates. Similarly, ANOVA is used to test the effect of irrigation methods on unit area productivity and on the per-ton cost of producing wheat. This determines the extent of a significant effect of the irrigation method used on both unit area productivity and the fixed, variable, and total costs on the farms. ANOVA is based on dividing the total variations in any of the mentioned variables into variations due to changes in factor levels or irrigation methods. This is explained by the levels of the relevant factor or irrigation method adopted, and random variations to calculate the F-test and the significance level at which the test value is considered significant. This test was conducted using SPSS packages.

Qualitative Response Function (Logistic Regression): Qualitative response functions are used when the dependent variable is non-scale, nominal, or ordinal. Nominal variables can be binary, meaning they take only two values: pass/fail or yes/no. Instead of predicting numerical or multi-binomial values, logistic regression estimates the probability that a sample belongs to a particular category using the formula:

$$\log\left(\frac{p}{1-p}\right) = a + b\,x$$

where p is the probability of the desired outcome occurring, and 1-p is the probability of failure.

Multinomial Logistic Regression: An extension of binary logistic regression, it is used when the dependent variable is multiclass rather than binary. Instead of predicting one of two categories, as in binary logistic regression, multiple logistic regression is used to predict an outcome that could be one of three or more categories. There will be a reference category among the multiple categories, and each time, the probability of its occurrence is compared to the probability of another category. Therefore, multiple logistic regression will represent multiple binary regressions when a category is compared to the reference category.

The variables for logistic regression can be classified as follows: The dependent variable and independent variables in a logistic model must have specific characteristics, namely:

Dependent variable: In this model, the dependent variable is a qualitative (nominal) variable that contains more than two categories. For example, if the goal is to predict the irrigation method (sprinkler, conventional, fixed), "irrigation method" is the dependent variable with three categories (9).

Independent variables: These can be qualitative or quantitative. The goal is to determine how they affect the category to which the dependent variable belongs. The equation for logistic regression is given as follows:

$$\log\left(\frac{p}{p-1}\right) = a + b_1x_1 + b_2x_2 + b_3x_3 \dots \dots + b_nx_n$$

Conditions for applying multiple logistic regression: The application of multiple logistic regression (MLR) relies on several conditions for applying analytical tools, obtaining results, and being able to analyze and interpret them. Before any analysis, secondary and primary data sources must be examined, whether the data are issued by statistical agencies or the entities being studied or whether the results are taken from questionnaires to which internal consistency and reliability criteria must be applied. Logistic regression is based on some basic conditions that must be met before application. The dependent variable must be a binary nominal variable for the binomial logistic regression type, a categorical variable for the multinomial logistic regression, or an ordinal variable for the ordinal logistic regression (4).

MLR conditions can be classified according to conditions and assumptions to ensure the accuracy of the results and the validity of the predictions. The following are important conditions that must be taken into account when applying this model:

1. Multiclass dependent variable: The dependent variable in MLR must be a qualitative variable containing more than two categories (such as three or more options).
2. Independence: MLR assumes independence between the levels of nominal variables.
3. Absence of multicollinearity: No significant overlap between the independent variables must exist i.e., the independent variables must not be highly correlated (4).
4. Linear relationship between the independent variables and the logistic function: The relationship between the independent and dependent variables does not have to be linear, as is the case in linear regression, but a linear relationship must exist between the independent variables and the natural logarithm of the probability function.
5. Multiclass distribution: MLR assumes that each category in the dependent variable is sufficiently distributed throughout the data (19).

Steps in logistic regression equation estimation: This is a fundamental tool in statistical analysis for expressing nominal problems in purely mathematical terms as a relationship between a set of independent and dependent variables. This is determined through a specific linking rule on the nature of the coupling and the predictability of behavior during the analysis of data from monitoring and simulation systems. The qualitative response function is used to analyze qualitative data through a set of steps, as follows:

- Data collection: This requires collecting data related to the independent and dependent variables based on the information and data obtained from the questionnaire.
- Data analysis: The logistic regression method is used to estimate a qualitative response model, using the adopted irrigation method as the dependent variable and the set of quantitative and nominal factors believed to influence the choice of irrigation method as the independent variables. This is used to extract coefficients of the independent variables that express the effect of the independent variables on the likelihood of adopting one irrigation method over another (5).
- Interpretation of results: The probability of an event occurring can be estimated based on the different values of the independent variables, which helps in making evidence-based decisions. This function is used particularly in logistic regression models, as they aim to understand how independent (explanatory) variables influence the probability of a particular event occurring.

The response function in logistic regression represents a logistic function that yields a value between 0 and 1, making it suitable for predicting probabilities. The qualitative function is used to convert linear outputs into probabilities which are calculated using the equation (14):

$$p(Y = 1/(x_1, x_2, x_3, \dots, x_n)) = \frac{1}{1 + e^{-(a+b_1x_1+b_2x_2+b_3x_3 \dots\dots + b_nx_n)}}$$

$$p(Y = 1/X) = \frac{1}{1+e^{-z}}$$

$$\frac{p_i}{1-p_i} = \frac{\frac{1}{1+e^{-z_i}}}{1-\frac{1}{1+e^{-z_i}}} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i}$$

By taking the natural logarithm of both sides, the logistic regression equation becomes as shown in Figure 1:

$$L = ln\frac{p_i}{1-p_i} = \ln(e^{z_i}) = z_i = B_0 + B_1x_1 + B_2x_2 + \dots + B_kx_k + e_i$$

where, z is the linear product of the independent variables; B_0 and B_i are the constants of the estimated model, i.e., the coefficients of the independent variables; and x_1, x_2, and x_3 are the independent variables.

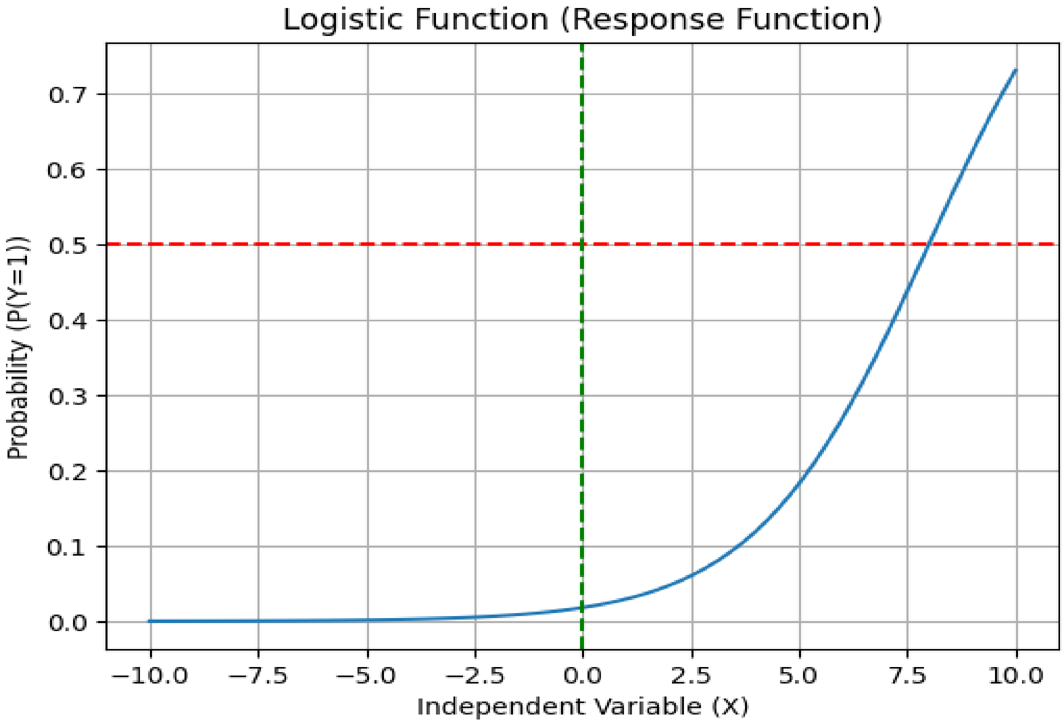


**Figure 1: Graph showing the qualitative response function.**

When dealing with qualitative variables having only two values, such as success or failure, presence or absence, the statistical models capable of analyzing this data are the qualitative response function or logistic regression, which is considered the best way to understand the relationship between the dependent and independent variables (14). The logistic form of the function shows how probabilities change nonlinearly with changes in the independent variables. There can be increasing or decreasing effects, demonstrating how an increase in the independent variable may lead to significant changes in probabilities in some ranges while the effect may be less in others (22).

Interpreting the results of logistic regression estimations: In interpreting the coefficients of independent variables in logistic regression, it should be remembered that the dependent variable is the natural logarithm of the odds ratio (odds ratio Ln p/(1-p)). Therefore, the coefficient represents the change in the natural logarithm of the odds ratio when the independent variable changes by one unit. As this may be difficult to understand, it is necessary to take the inverse of the natural logarithm of the coefficient (Exp.B,s) to represent the change in the odds ratio when the independent variable changes by one unit. Multiplying this by the original odds ratio gives the odds ratio after the change, which, when equated to p/(1-p), allows a determination of the new probability after the change. As such, the level of influence of a change in the factor on the probability of an event depends not only on the value of the coefficient but also on the odds ratio before the change or on the probability value before the change. A coefficient value of 0.5 will have an inverse logarithm of 1.6487 (21).

## Results and Discussion

The Impact of Irrigation Methods on Productivity and Costs in the Sample Farms: The irrigation method adopted in the farms is expected to affect the productivity per dunum and the average cost of producing a ton of wheat (13). An analysis of variance was conducted for each farm unit's productivity according to the irrigation method and the rates of fixed, variable, and total costs. Table 1 shows productivity per dunum and the average cost of producing a ton of wheat according to the irrigation method, the test value, and the level at which it is significant.

**Table 1: The effect of irrigation method on dunum productivity and the average costs of the produced ton.**

| Irrigation method | | Productivity in tons/dunum and costs ('000 dinars) | | | |
|---|---|---|---|---|---|
| | | AP | ATC | AVC | AFC |
| **Conventional** | | .8900 | 447.0081 | 285.4621 | 161.5460 |
| **Pivot sprinkler** | | .9963 | 401.9839 | 270.7162 | 131.2678 |
| **Fixed sprinkler** | | 1.0426 | 449.1080 | 297.9198 | 152.3562 |
| **Total** | | .9823 | 419.4241 | 278.4573 | 141.1682 |
| **Analysis of variance results** | F. | 5.649 | 1.713 | .758 | 6.243 |
| | Sig | 0.005 | 0.185 | 0.471 | 0.003 |

As shown, the traditional irrigation farms had the lowest productivity at 890 kg/dunum, followed by the pivot (996 kg/dunum) and fixed sprinkler irrigation farms which excelled at 1042 kg/dunum.

No significant differences appeared between average total production costs per ton, which ranged from 401,000 dinars/ton for the pivot sprinkler system and 449,000 dinars/ton for fixed sprinkler irrigation. No significant differences in the different irrigation methods were seen in terms of variable costs which ranged from 270,000 and 297,000 dinars/ton for the pivot and fixed sprinkler systems, respectively. Significant differences were seen in fixed cost rates with the highest value seen in the traditional irrigation system at 161,000 dinars/ton and the lowest at 131,000 dinars/ton for pivot spraying.

Water Use Efficiency According to Irrigation Method: Although farms may not show any variation in costs, they may differ in their water use (10). Since water is not included in the costs, farmers often believe water is costless but valuable and must be used efficiently. There is a direct relationship between water efficiency and productivity per cubic meter of water (6). It can be measured by the plants' water requirement relative to the amount of water pumped. The lower the water waste, the higher the efficiency, and the greater the waste, the lower the efficiency (8).

If the wheat crop requires 500 mm during the season and the rainfall average in the study year was 65 mm, the required supplementary irrigation should be 435 mm. Therefore, the requirement for a dunum of wheat will be 1,088 cubic meters. Water productivity per cubic meter and water use efficiency was calculated using the following formula (22):

$$WE = \frac{NW}{WU} * 100$$

where, WE is water-use efficiency, NW the amount of water required for the area, and WU the amount used.

Table 2 shows that fixed sprinklers in the sampled farms had the highest water unit productivity at 0.758 kg/m³, followed by the pivot (0.741 kg/ m³) and conventional irrigation (0.505 kg/m³) systems. As for water use efficiency, it peaked in pivot sprinklers at 81%, followed by fixed sprinklers at 79% while the lowest efficiency was with traditional irrigation at 62% (15).

**Table 2: Water efficiency and productivity in the wheat farms based on irrigation method.**

| Irrigation method | Quantity of water used in the sample (m3/dunum) | Productivity per cubic meter of wheat | Water use efficiency (%) |
|---|---|---|---|
| **Conventional** | 1750 | 0.505 kg/m³ | 62 |
| **Pivot sprinkler** | 1344 | 0.741 kg/m³ | 81 |
| **Fixed sprinkler** | 1375 | 0.758 kg/m³ | 79 |

Factors Determining the Irrigation Method Used: The choice of irrigation method is influenced by various technical and economic factors. Since the method used is the dependent variable, which is qualitative rather than quantitative (16), logistic regression will help determine the extent of the influence of the factors on its use in the sample farms. It takes into consideration the irrigation method as the dependent variable, and other factors such as the area involved, the farmers' educational attainment, the nature of land ownership, the boundaries of the land, and others as the independent variables (16). This was done using multiple logistic regression, taking into account the natural logarithm of the odds ratio as a function of the independent variables, according to the following formula:

$$ln\frac{p}{1-p} = \mathrm{a} + B_1X_1 + B_2X_2 + \cdots + B_kX_k$$

The results of the estimation showed that the sample was distributed according to the descriptive variables seen in the model that proved its significance. This included the weighting ratio of the irrigation method used, which the higher it was, the more likely it would be to adopt the irrigation method, and vice versa. As for the independent variables, it was proven that area had a significant impact, as the model included three descriptive variables represented by the type of land ownership, the nature of the farm's external borders, and the farmer's educational attainment.

Table 3 shows the distribution of descriptive variables in the study sample (17). Of the total farmers sampled, 81 adopted the sprinkler irrigation method, 38 the traditional method, and 22 used the fixed sprinkler method. The number of educated farmers in the study sample was about 54%. Agricultural contract farming dominated at 84% while 11% of the farmers had agricultural title deeds to the farms. Most farms in the study sample had semi-open lateral borders, meaning they were located in semi-desert areas that could be expanded laterally.

**Table 3: Distribution of the study sample according to the variables of the estimated logistic regression model.**

| Descriptive Model Variables | Variable Levels | Sample | |
|---|---|---|---|
| | | Number | Percentage |
| Dependent Variable (Irrigation Method) | 1.00 Center-pivot | 81 | 57.4 |
| | 2.00 Conventional | 38 | 27.0 |
| | 3.00 Fixed sprinkler | 22 | 15.6 |
| Educational Attainment | Uneducated | 65 | 46.1 |
| | Educated | 76 | 53.9 |
| Ownership Type | Agricultural title deed | 16 | 11.3 |
| | Contract | 118 | 83.7 |
| | Ownership | 7 | 5.0 |
| Boundaries | Semi-open | 92 | 65.2 |
| | Restricted | 49 | 34.8 |
| Total | | 141 | 100.0 |

The results of the analysis are shown in the tables below. The MLR analysis shows that area owned by the farmer, ownership type, and the nature of the external borders had a significant impact on the type of irrigation method adopted. However, educational attainment did not significantly impact the irrigation method adopted according to the significance levels of the chi-square values and the analysis tables obtained from the SPSS program.

**Table 4: Chi-square and pseudo-correlation test results for model testing.**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| **Intercept Only** | 259.050 | | | |
| **Final** | 106.356 | 152.694 | 10 | .000 |

| Pseudo R-Square | |
|---|---|
| Cox and Snell | .661 |
| Nagelkerke | .775 |
| McFadden | .563 |

| Effect | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| **Intercept** | 106.356[a] | .000 | 0 | . |
| **Area** | 125.135 | 18.779 | 2 | .000 |
| **Education** | 106.462 | .106 | 2 | .949 |
| **Ownership** | 123.394 | 17.038 | 4 | .002 |
| **Boundary** | 152.225 | 45.869 | 2 | .000 |

Table 5 of the logistic regression coefficients shows that farmer-owned area had a highly significant impact on the irrigation method adopted. Since the traditional irrigation method was considered the reference in the model, the area coefficient was 0.036, representing the change in the natural logarithm of the probability ratio when the area increases by one dunum. By taking the inverse of its natural logarithm, it reached 1.037, as shown in the table. This indicates that an increase in the area by one dunum is followed by an increase of 0.037 in the probability ratio for adopting the pivot sprinkler irrigation method.

In contrast, the area coefficient in the fixed sprinkler irrigation method indicated that the probability of adopting it decreases as the area increases because the area coefficient in the model reached -0.006, which, by taking the inverse of its natural logarithm gave a constant value of 0.472. This means that a decrease follows an increase in the area by one dunum in the probability of adopting the fixed sprinkler irrigation method (11).

Although not significant, the educational attainment coefficient showed a 0.2% increase in adopting the fixed or pivot irrigation methods among educated farmers. There was an increased likelihood of them adopting the sprinkler irrigation method for their wheat cultivation. As for ownership type, owners of contracted lands had a greater desire and tendency to adopt modern irrigation methods while the pivot irrigation method was less likely to be used by those whose lands had agricultural title deeds. The effect of this factor on adopting fixed sprinkler irrigation was inverse, with owners of contracts or agricultural title deeds less interested in employing this system compared to those with title deeds.

Land boundaries and boundary restrictions significantly impacted the adoption of pivot irrigation, with more open or semi-open boundaries increasing the likelihood of this system being used. The probability of adopting the center pivot irrigation method was more than 250 times higher among farmers with no land boundary restrictions than in farms with restricted boundaries which cannot be manipulated or exceeded. This indicates the extent of the impact of ownership restrictions and fixed boundaries on the adoption of center-pivot irrigation methods.

**Table 5: Logistic regression model coefficients for the effect of some variables on irrigation method adoption.**

| | Variable | B | SD | Wald | df | Sig. | Exp (B) |
|---|---|---|---|---|---|---|---|
| **1.00** | **Intercept** | -8.816- | 2.582 | 11.662 | 1 | .001 | |
| | **Area** | .036 | .011 | 9.956 | 1 | .002 | 1.037 |
| | **[Education = educated]** | .124 | .848 | .021 | 1 | .884 | 1.132 |
| | **[Education = uneducated]** | $0^b$ | . | . | 0 | . | . |
| | **[Ownership = Agricultural title deed]** | -.596- | 1.957 | .093 | 1 | .761 | .551 |
| | **[Ownership = contract]** | 2.953 | 1.615 | 3.345 | 1 | .067 | 19.164 |
| | **Ownership** | $0^b$ | . | . | 0 | . | . |
| | **[Boundary = semi open** | 5.773 | 1.523 | 14.363 | 1 | .000 | 321.545 |
| | **[Boundary = restricted]** | $0^b$ | . | . | 0 | . | . |
| **3.00** | **Intercept** | .558 | 1.132 | .243 | 1 | .622 | |
| | **Area** | -.006- | .008 | .518 | 1 | .472 | .994 |
| | **[Education = educated]** | .177 | .564 | .098 | 1 | .754 | 1.194 |
| | **[Education = uneducated]** | $0^b$ | . | . | 0 | . | . |
| | **[Ownership = Agricultural title deed]** | -2.142- | 1.243 | 2.968 | 1 | .085 | .117 |
| | **[Ownership = contract]** | -.698- | 1.003 | .485 | 1 | .486 | .498 |
| | **Ownership** | $0^b$ | . | . | 0 | . | . |
| | **[Boundary = semi open** | -.354- | .786 | .202 | 1 | .653 | .702 |
| | **[Boundary = restricted]** | $0^b$ | . | . | 0 | . | . |

As seen in Table 6, the estimation model can explain farmers' tendencies towards adopting the irrigation method by 95% for the center pivot irrigation system and 84% for traditional sprinkler farmers. However, it was able to explain a small percentage in the field of fixed sprinkler irrigation farmers, at only 14%. The model explained about 80% of farmers' tendencies towards the irrigation method in the total sample.

**Table 6: Predictive efficiency of the estimated model.**

| Observed | Predicted | | | |
|---|---|---|---|---|
| | 1.00 | 2.00 | 3.00 | Percent Correct |
| 1.00 | 77 | 4 | 0 | 95.1 |
| 2.00 | 5 | 32 | 1 | 84.2 |
| 3.00 | 3 | 16 | 3 | 13.6 |
| Overall Percentage | 60.3 | 36.9 | 2.8 | 79.4 |

## Conclusions

1. The adopted irrigation method significantly impacts farm productivity, as fixed sprinkler irrigation outperformed the other methods followed by center pivot irrigation. Therefore, it can be argued that switching to sprinkler irrigation methods increases productivity per unit area, and farmers should be encouraged to adopt the system.
2. Water unit productivity was the highest for fixed sprinkler irrigation at 0.758 kg/cubic meter of water, valued at approximately 620 dinars, compared to 0.741 kg/cubic meter (607 dinars) for center pivot irrigation, and 0.505 kg/cubic meter (414 dinars) for traditional irrigation.
3. The highest water use efficiency was achieved using the center pivot irrigation method at 81% followed by the fixed sprinkler irrigation at 79% efficiencies while the lowest at 62% was for the traditional irrigation method, indicating the potential for increasing water use efficiency through the transition to sprinkler irrigation methods.
4. The logistic regression model showed that farm area significantly impacted the irrigation method used with greater land area tending towards the adoption of center pivot irrigation. The probability of adopting center pivot irrigation increased by 0.0037 for every dunum of area. The opposite occurred for the fixed sprinkler irrigation method which was more likely to be adopted for smaller farm size areas.
5. Ownership restrictions and fixed boundaries limited the adoption of center-pivot irrigation, with open boundaries surrounding the farm increasing the probability of adopting the system by approximately 250 times compared to closed boundaries. This explains the increasing use of center-pivot irrigation in desert lands. Therefore, flexibility in changing boundaries is recommended to encourage adopting modern irrigation methods.
6. Educated farmers were more inclined to adopt center pivot irrigation methods than their uneducated counterparts, although the coefficient was not statistically significant. This indicates the need for education to promote the adoption of modern irrigation methods.
7. Farmers who own their land under contracts were likelier to adopt center pivot irrigation, unlike those who own land under agricultural title. Therefore, allowing flexibility in land ownership laws is recommended to encourage the adoption of modern irrigation methods.

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