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To cite this article: Z. H. Mahmood *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1060** 012143

Measuring Technical Efficiency and Determining the Factors Affecting the Inefficiency of Wheat Farmers in Iraq (Diyala Governorate as an Applied Model) for the Season 2021

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Abstract. The study aimed to estimate the technical efficiency and the factors affecting the inefficiency of wheat production farms. The Pareto curve was used to determine the importance of the problems facing farmers in the production process ،the actual and potential production and the number of production losses in the study area were also calculated. A random sample of 100 wheat farmers was taken in Diyala Governorate including five districts The Stochastic Frontier Analysis was estimated using the Maximum Likelihood method. The results indicated that wheat production in Diyala Governorate is affected by the explanatory variables (seeds, compound fertilizers, urea fertilizers, pesticides, mechanical work, and human work). The total elasticity of the productive factors was 0.845, which implies that the farmers carry out their agricultural operations when there is a decreasing return to scale. The value of γ was 84%, which means that about 84% of the variances in inefficiency were due to factors under the control of the farmers. The technical efficiency ranged between (77.41 – 86.91%). The total actual production was 2,3049.955 tons, while the potential production was 2,754.865 tons. Thus, the production loss was 2744.865 tons. It can be concluded that farmers use resources in a different way and that they work in nonhomogeneous conditions. The study recommends following scientific methods in farm management and redistributing the economic resources to ensure the achievement of the same level of production or higher in light of reducing costs

Keywords. Stochastic Frontier, Pareto curve, Production loss, Maximum Likelihood.

1. Introduction

Wheat is one of the most important grain crops in terms of production and consumption. Countries, including Iraq, are working hard to increase the agricultural area planted by this crop by exploiting all the possibilities available [1]. The wheat crop is cultivated in many countries of the world by depending on rain (domestic cultivation) or in irrigated production areas. In Iraq, it is grown using both methods. The total lands planted with wheat in Iraq amounted to 8573628 dunums, with a production rate of 6238392 tons, while the average productivity reached 841.4 kg/dunums for the year 2020. The area cultivated by the democratic method reached 2615591 dunums, which constituted 30.5% of the total areas planted with the wheat crop, with a production rate of 1230562 tons (i.e. 19.7% of the total production of the crop), with a productivity of 470 kg/dunums for these lands.
In terms of productivity, it was noted that the average productivity in Iraq was 841.1 kg/dunum, which is considered good productivity. This can be attributed to the use of modern technologies such as sprinklers of various types that are widely used all over the country, as well as the use of high-productivity varieties [2].
Diyala governorate ranked fifth in terms of the total domestic production of wheat. The governorate produced an amount of 571748 tons accounting for 9.16% of the total production of the crop in Iraq. This relatively high percentage reflects the importance of the governorate in terms of production. The total area planted with the crop reached 680606 dunums and constituted 7.94% of the total lands planted with the crop in Iraq.
Although the agricultural sector in Iraq has witnessed many achievements, there are still many challenges facing sustainable development in producing enough food that meets the requirements of food security. The challenges are mainly represented by the limited resources of land and water, the competition for water for different purposes and rationalizing their use, the existence of dry seasons, and the global rise in the prices of production inputs, which negatively affected agricultural production in general and the wheat crop in particular. These factors may lead to a deviation in the use of agricultural resources from optimal use. The importance of the study comes from its focus on the technical efficiency (TE) of wheat production which covers 23.4% of the global need for food. It is also a major food source for about 40% of the world's population and provides 20% of calories and 55% of the total carbohydrates. It is also a raw material for many food industries (bread, pasta, biscuits) and contributes to creating job opportunities for a large sector of society [3]. On the other hand, achieving efficiency for the available agricultural resources is a major goal for decision-makers. The relative scarcity of resources and low access to technology justify more studies on efficiency because such studies can improve the efficiency of the farm in the use of available resources and production methods. Many Arabic and international studies have addressed the TE [1-14]. However, Only a few studies focused on this issue in Iraq [15-20]. The study aimed to estimate the TE and associated factors of wheat production farms through stochastic frontier analysis (SFA). The Pareto curve was used to determine the importance of the problems facing farmers in the production process. The actual and possible production and the amount of production loss were also calculated. The study is based on the hypothesis that most of the included farmers do not optimally use the resources, which leads a resource wasting. This negatively affects the TE of farmers.

2. Materials and Methods

2.1. Data Collection

The study depended on the primary data obtained from its sources. The data were collected through a personal interview with farmers in Diyala Governorate. The field survey included five districts in Diyala Governorate (Baladrooz , Baquba, Muqdadiya, alkhalis, Khanaqin) using a questionnaire for 100 wheat farmers (representing 6.6% of the total farms) in study region .

2.2. Data Analysis

The Stochastic Frontier Analysis (Frontier Version 4.1 software) with Maximum Likelihood were used in estimating TE and determining the factors affecting inefficiency.

2.3. Technical Efficiency in Crop Production

Technical efficiency in crop production can be defined as a farmer's ability to maximize outputs at certain set of inputs and technology. The degree of technical inefficiency reflects an individual farmer's failure to attain the highest possible output level. The highest possible output, using the available inputs and technology, is represented by the production frontier. Figure 1 shows a production frontier in which the degree of TE is conditional to the level of inputs [21]. Output (Y) is shown on the y-axis and inputs (X) on the x-axis.

The distinction between technological change and TE is very important. Technological change reflects a shift of the production frontier, as new technologies enable output per unit of input to increase [22].

Technical efficiency, on the other hand, explains the difference between potential and observed yield for a given level of technology and inputs. Initial studies to measure TE used the deterministic frontier approach, which assumes that any deviations from the frontier are due to inefficiency. In wheat production, this would imply any farmer producing below the frontier was inefficient. However, the deterministic ontier ignored factors beyond the control of the farmers, such as weather conditions, which could influence efficiency. Thus the results of the deterministic approach were sensitive to the selection of variables and to data errors (4, 18, 28). independently developed the stochastic frontier approach to address some of the limitations of the deterministic frontier approach. In the new approach, the error term consists of two components, one being random and the other being a one-sided residual term representing inefficiency. The stochastic frontier approach has subsequently been refined in various ways.

This study adopts the stochastic frontier approach to assess the technical efficiency of small-holder wheat producers in Diyala. province

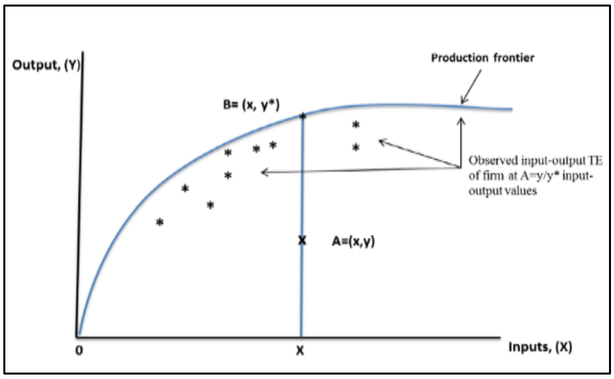

Figure 1. Technical efficiency of firms in input-output space [23].

The TE of wheat production farms was estimated using the stochastic frontier analysis method according to the Cobb-Douglas production function to estimate the achieved efficiency. The reason beyond choosing the SFA method was that it is suitable for studying the efficiency of farms that suffer from problems as well as the ability to explain the variance in terms of independent variables [24]. In this method, there was a focusing on the basic inputs used in production. The program (Frontier Version (4.1) was used in calculating and estimating the TE. This program allows estimating random production limits and obtaining estimates for the maximum parameters of the function. The estimation process goes through three steps [25]:

- In the first step, the Ordinary Least Squares (OLS) method was used to obtain unbiased linear parameters (BLUE) of the standard model except for the b_o value.
- In the second step, the corrected least squares (COLS) method was used to obtain unbiased linear parameters, including b_o [26].

Technical efficiency, in this case, was defined as the ratio of actual production to expected production, which takes values between one and zero [10], and is obtained according to the following equation (1):

$$TE = \frac{Y_i}{Y_i^*} = \frac{e^{(X_i\beta - u_i)}}{e^{(X_i\beta)}} = e^{(-u_i)} \tag{1}$$

The stochastic frontier production function differs from the production boundary function in the formula of Cobb-Douglas through the addition of stochastic error which represents the measurement error $(V_i)$for random error (U_i)which is represented by inefficiency [27].
By taking the logarithm of the Cobb-Douglas function and adding the error terms, we get:

$$\text{Ln } Y_i = \beta_i \text{Ln } X_i + (V_i - U_i) \tag{2}$$

Equation (2) can be written in another form as follows:

$$\text{Ln}Y_i = \beta_i \text{Ln } X_i + e_i \tag{3}$$

- In the third step, the maximum probability estimates for the parameters of the stochastic boundary production function were obtained, using the Maximum Likelihood method according to the Cobb-Douglas production function.

The specific model for TE was obtained using the following relationship:

$$TE_i = e^{-ui^{\wedge}/\Sigma\beta_i} = e^{(-E(\frac{ui}{\varepsilon i})/\Sigma\beta_i)} \tag{4}$$

The value of TE ranges between zero and one, where one indicates that the farm is fully efficient.
In this study, the model was formulated for the purpose of describing the most important variables that are supposed to affect the production of wheat crops in the Diyala Governorate for the season 2021. The stochastic frontier production function using the Cobb-Douglas model in the research sample included the following variables:

$$\text{Lm } Y_i = \beta_o + \beta_1 \text{Ln } X_{1i} + \beta_2 \text{Ln } X_{2i} + \beta_3 \text{Ln } X_{3i} + \beta_4 \text{Ln } X_{4i} + \beta_5 \text{Ln } X_{5i} + (v_i - u_i) \tag{5}$$

whereas:
The dependent variable (y): represents the total production of the wheat crop actually achieved by the farmers' holdings, estimated in tons.
Independent variables include the following:

1. Total seed quantity (X_1): It represents the actual quantity of seeds used by farmers, estimated in (kg).
2. Pesticides (X_2): represents all pesticides and liquid activators that were used during the productive season, estimated in (liters).
3. Compound fertilizer (X_3): The total amount of fertilizer (kg) during the productive season.
4. Compound fertilizer (X_4): The total amount of fertilizer (kg) during the productive season.
5. Number of mechanical work hours (X_5): The total mechanization services used during the season are estimated by the total number of hours. These services included.
6. The number of human work hours (X_6): represents the manual labor services (family and wages) that were used during the season, estimated in (hours).

Vi: A random variable or measurement error due to variables not under the control of the farmer, such as rain, for example.
Ui: a non-negative random variable related to variables that are under farmer control, such as experience and educational level for example, and it represents technical inefficiency.

$$U_i = \delta_o + \sum \delta_i Z_i \quad (6)$$

The inefficiency model in the research sample included social and economic characteristics of farmers and performance indicators within the farm:

$$U_i = \delta_o + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} \quad (7)$$

whereas:
Z_1: the number of family members (persons)
Z_2: years of experience
Z_3: Years of Education
Z_4: possession (private property = 0, rent = 1)
The value of the coefficient δ expresses the contribution of technical inefficiency in explaining the total variance of the function, and it lies between zero and one. If δ = 0, then all deviations from the frontiers are due to factors beyond the control of the farmer, but if δ = 1, then all deviations are due to inefficiency [28].

2.4. Pareto Curve
The Pareto curve was used to determine the importance of the problems facing farmers in the production process. Pareto Diagram is a special model used in parallel with the cause and effect diagram to support process improvement by identifying and prioritizing problems. The chart consists of vertical columns and a cumulative curve combined together by one plot, where the vertical axis represents the number of occurrences (frequency) and the horizontal axis represents the reasons or selected elements.

2.5. Estimation of Production Loss
To calculate the production loss due to inefficiency, the possible production values were extracted for each farm separately, according to the following mathematical relationship [29].

$$Y_i^* = \frac{Y_i}{TE_i} \quad (8)$$

whereas:
Y_i^*: The amount of possible production of the farm (i).
Y_i: The amount of actual production of the farm (i).
TE_i: TE of production of the facility (i).
Accordingly, it is possible to estimate the amount of production loss by subtracting the actual production from the possible production:

$$\text{Amount of production loss} = \text{Possible production - Actual production.}$$

3. Results and Discussion
The stochastic frontier production function of wheat was estimated using the Maximum Likelihood method. The results of the Cobb-Douglas function and the T-test were obtained. The variance of the coefficients (σ^2)and the gamma (γ wase also estimated. Furthermore, the economic and social variables of farms that affect the level of inefficiency were estimated. It is worth noting that the negative values of the inefficiency variables indicate the positive relationship between the level of TE and the variables included in the model. That is, the positive trend of these variables indicates a decrease in TE with an increase in the influence of these factors.
Table (1) shows the estimates of the Maximum Likelihood of the SPF using the Cobb-Douglas model of the wheat crop. The results indicated that wheat production in Diyala Governorate is affected by the

explanatory variables which were seeds, compound fertilizer, urea fertilizer, pesticides, mechanical work, and human work as follows:

- Seeds: There was a positive and significant relationship between the number of utilized seeds and the production of wheat crops. The elasticity of the seed variable was 0.305, which implies that a 1% increase in the number of seeds (without plant intensification) leads to an increase in production by 0.305%.
- Compound fertilizer: There was a positive and significant relationship between compound fertilizer and wheat production. The elasticity of the compound fertilizer was 0.052, meaning that a 1% increase in compound fertilizers associated with a 0.052% increase in wheat production.
- Urea fertilizer: There was a positive relationship between urea fertilizer and wheat production. The elasticity of urea fertilizer was 0.068, meaning that when urea fertilizer increased by 1%, wheat production would increase by 0.068%.
- -Pesticides: As for the pesticide supplier, the elasticity was 0.288, meaning that an increase in the number of pesticides by 1% leads to an increase in wheat production by 0.288%. The production elasticity of the pesticide was positive and significant at 5%.
- Mechanical work: the elasticity value was (-0.018), indicating the inverse relationship between mechanical work and wheat production. Such a result indicated that mechanical work does not significantly affect wheat production.
- Human work: it was found that an increase in the number of human working hours by 1% leads to an increase in wheat production by 0.112%. The productive elasticity of the human labor resource was positive and significant at 5%.

The total elasticity of the productive factors included in the function was about 0.843, which was less than the correct one. This implies that the farmers carry out their agricultural operations when in a decreasing return to scale. That means farmers carry out these operations in the economic stage of production (the second stage).

3.1. Technical Inefficiency Form

This model shows the different effects of the explanatory variables on the technical inefficiency of wheat farms. The results showed that the inefficiency is affected by a set of economic and social factors and performance indicators within the farms, such as the number of family members, experience, education, and type of possession. The results indicated that experience, education, and farm size had a negative impact on technical inefficiency, the negative sign in the inefficiency model implies that the variables (experience, number of family members, and type of possession) increase the TE of wheat production in the study area. Similarly, the increase of family members increases the TE as it provides the necessary labor during the season, which encourages cultivating the crop in the study area. The type of possession had a negative impact on inefficiency, which means that private ownership increases TE. This can be attributed to the behavior of the farmers. Those working in their own farms have a long-term investment which improves the use of assets.

As for the educational level, it had a positive effect on the technical inefficiency. The results showed that the increase in the years of education makes the farmer leave the farm work and search for other proper work outside the farm.

The results indicated that the value of γ was 84% and significant at the 1% level, which means that about 84% of the variances in inefficiency were due to factors under the control of the farmers and that 8% were due to random factors outside their control. This implies that the OLS method is insufficient to explain the inefficiency differences between farmers, and these results agreed with many previous studies [30-32].

Additionally, the variance value (σ^2) was estimated at 0.065, which is statistically significant at 1%. It indicates that the effects of technical inefficiency were the most important component in the total change in wheat production in the study area.

Table 1. Estimation of the stochastic frontier function using the maximum likelihood method for wheat production in Diyala Governorate.

Variables	coefficient	Estimated coefficient values	standard-error	t-ratio
Constant	β_o	4.223	1.310	3.224***
Pesticides	β_1	0.305	0.087	3.506***
Quantity of Compound fertilizer	β_2	0.052	0.012	4.333***
Quantity of urea fertilizer	β_3	0.068	0.034	2.000**
Quantity of pesticides	β_4	0.288	0.119	2.420**
Mechanical work hours	β_5	-0.018	0.042	-0.429
Number of hours of work	β_6	0.112	0.046	2.435**
Inefficiency model				
Constant	δ_o	0.452	0.293	1.543
number of family members	δ_1	-0.822	0.174	-4.724***
Experience	δ_2	-0.212	0.070	-3.029***
Education	δ_3	3.750	15.957	0.235
Possession	δ_4	-0.823	0.215	-3.828***
Returns to Scale (RTS)		0.902		
sigma-squared(σ^2)		0.065	0.018	3.611***
Gamma (γ)		0.840	0.001	840***
Log-likelihood		45.022		

Source: Calculated using Frontier Version 4.1
*** Significant level of significance 1%, ** Significant level of significance 5%, Significant level of significance 10%.

3.2. Technical Efficiency Estimation

By analyzing the data using the SFP, it was possible to measure the average TE of wheat crop production in the most important crop-producing districts in Diyala Governorate (Khalis, Baladrooz, Muqdadiyah, and Khanaqin) using the Frontier Version 4.1 program.

Table (2) shows that the average TE of the wheat crop in the Diyala governorate was 0.83. This entails that the farmers in the sample have to produce the current level of the crop or higher using ≤ 83.058% of the inputs that are used to reach the optimum TE. The production can be increased by 0.17% (as the average for each farmer) if the inputs were used correctly. The TE ranged between (77.41 – and 86.91%) and it was found that the farms of the Baquba district had the highest yield of wheat with a limited number of inputs. On the other hand, the lowest level of TE was in Al-Muqdadiya and Al-Kahlis (77.41%). Accordingly, these farms have to use 22.59% or less of the current inputs to reach the stage of optimum efficiency and produce the current level of wheat crop or higher.

Table 2. Actual and potential production and the amount of production loss for wheat crop in the districts of Diyala Governorate for the season 2021

Districts	Average Technical Efficiency %	Actual production (tons)	Potential production (tons)	Production loss (tons)
Baladrooz	85.75	5296.071	6176.176	880.1051
Baquba	86.91	7918.887	9111.595	1192.708
Muqdadiya	85.21	3727.675	4374.692	647.0169
alkhalis	80.01	3296.071	4119.574	823.5028
Khanaqin	77.41	2811.251	3631.638	820.387
Average efficiency	%83.058	23049.955	27750.97	4701.014

Source: Calculated by the researcher based on the questionnaire.

3.3. Estimation of Production Loss

The actual and potential production and the amount of production loss in the study area were calculated. In addition, the potential production was calculated for each farm separately, and the results were presented at different levels of efficiency.

Table (3) shows the actual and potential production and the amount of production loss. The total actual production in a sample of wheat farmers in Diyala Governorate under the current management of agricultural operations was 2,3049.955 tons. The potential production was 2,754.865 tons. Thus, the production loss was 2744.865 tons. Given that the price of a ton of the crop is 500 thousand dinars during the production season, the production loss amounted to about 1.377 million. To reach the potential production level, farmers have to modify the use of inputs included in agricultural operations in order to increase production. This will only be performed through continuous training and extension to farmers on the management process of the crop.

3.4. Production Problems and Proposed Solutions from the Farm's Point of View

3.4.1. The Problems and Difficulties

Farmers' opinions were taken about the problems and difficulties facing wheat cultivation in Diyala Governorate. The opinions varied greatly according to different districts. Table (2) shows the problems and determinants which were listed in descending order according to the farmer's opinion. The most important production problems facing wheat farmers in the study area were the delay in farmers' entitlements, which led to the purchase of production requirements (seeds, fertilizers, and pesticides) on credit. This can increase the production costs, as it constituted 68% of the total number of answers, while 65% believed that the main problem is the high prices of seeds processed by seed companies. A decrease in the levels of the Tigris River due to the lack of rainfall and the instability of weather conditions was the next most important determinant, which accounted for 55%, then the failure to conduct agricultural operations on time and the repeated cultivation of the crop in the same area by 48%, 45%, respectively. Finally, the weakness of the digging operations of rivers and drains, and the lack of extension specialized guidance centers that provide services to farmers in the study area accounted for 20% and 15% of the answers, respectively (Figure 2).

Table 3. Problems and difficulties of cultivation and production of wheat crop in Diyala Governorate for the season 2021.

	The problem	**Frequency**	**The ratio %**	**Cumulative percentage %**
1	The absence of specialized extension centers that provide services to farmers in the study area.	11	3.30	3.30
2	High prices of seeds provided by seed companies.	65	19.52	22.82
3	Delay in farmers' entitlements with purchasing of production requirements on credit, which led to an increase in their costs	68	20.42	43.24
4	Agricultural operations are not carried out on time	45	16.22	59.46
5	Repeat planting of the crop in the same area.	45	13.51	72.97
6	Infection of the crop by diseases and insects.	15	4.50	77.48
7	Weakness of digging operations of the drains and rivers.	20	6.01	83.49
8	Low rainfall and unstable weather	55	16.52	100.00

Source: collected and calculated from the field survey

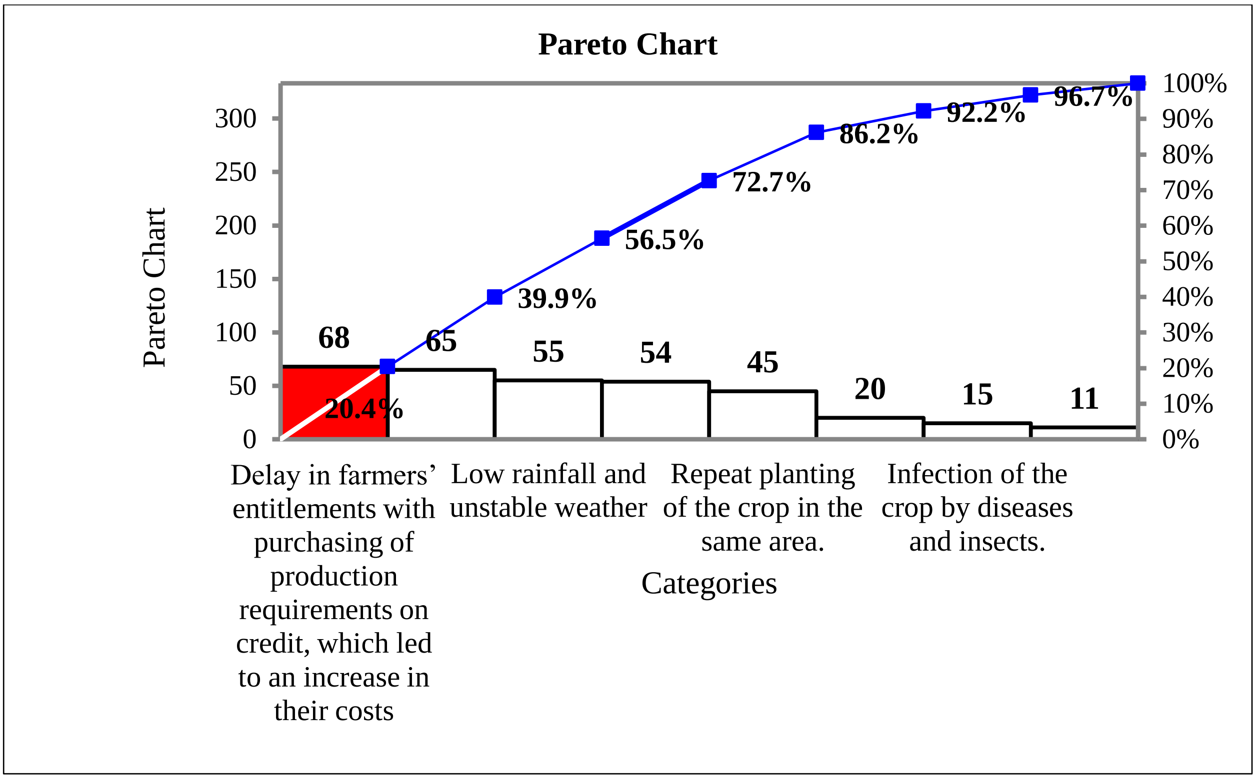

Figure 2. Pareto curve Problems and difficulties of wheat cultivation in Diyala Governorate for the season 2021.

Conclusions and Recommendations

In light of the present findings، the results of TE indicate a variation in the averages between the districts of Diyala Governorate. Thus, it cab concluded that farmers use resources in a different way and that they work in a production environment with nonhomogeneous conditions. Also, the lack of TE can mainly be attributed to the performance level on the farm. The study showed that there was a production loos in the study sample as a result of the lack of TE in production, which caused wastage in the use of resources and negatively affected the income of the farmer. The farmers' response showed that the delay in the obtaining of financial dues to farmers for periods that may exceed a year is the most important problem facing farmers, as it ranked first. This issue directly affects the farmer's ability to fund the production process in the next season. So farmers are forced to purchase production requirements at very high prices and in an exploitative manner from dealers of these supplies by credit and future payments. Therefore, makers-decision must deal with this issue by paying the financial obligations to the farmers on due.

The researcher recommends following scientific methods in farm management to alleviate the insufficiency of TE resulting from poor crop management and redistribute the economic resources to ensure the achievement of the same level of production or with reduced costs. There is also a need using of modern means and techniques to ensure the optimal exploitation of productive resources that achieves TE.

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