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AGRIBUSINESS

Measurement of resource use efficiency in corn production: a two-stage data envelopment analysis approach in Turkey

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ABSTRACT: *This research analyzed the efficiency situation of corn farms operating in the Adana province of Turkey. In this context, required farm management data were collected from 111 corn farmers by using face to face survey method during the 2019-2020 cultivation season. To determine the technical efficiency (TE) levels of corn farms, Data Envelopment Analysis (DEA) was applied. Furthermore, factors that cause the inefficiency in corn farms were detected by using the Tobit regression model. According to research results, the average TE levels of corn farms in the research area under the variable return to scale conditions are reported as 0.887 (111 farms). These results suggested that if farms reduced their input use by 11.3% on average, they can achieve the same output level and be able to reach full technical efficiency. The most ineffective source in terms of farms performance is machine expenditures with 68.2% of excessive use followed by labor use. In this regard, mechanization modernization, education and training of the labor force and more sensitive fertilizers and pesticide use can increase the efficiency of corn farms. Results of the Tobit regression model indicated that factors such as experience, education, number of tractors and size of the irrigated area positively influenced the TE, whereas family size in corn farming has a negative effect.*
Key words: *technical Efficiency, corn farms, Data Envelopment Analysis, Tobit Model.*

Medição da eficiência do uso de recursos na produção de milho: uma abordagem de análise de dados em duas fases na Turquia

RESUMO: *Esta pesquisa tem como objetivo analisar a situação de eficiência das fazendas de milho operando na província de Adana, na Turquia. Neste contexto, os dados necessários de gestão da fazenda foram coletados de 111 produtores de milho usando o método de pesquisa frente a frente durante a temporada de cultivo de 2019-2020. Para determinar os níveis de eficiência técnica (TE) das fazendas de milho, foi aplicada a Análise Envoltória de Dados (DEA). Além disso, os fatores que causam a ineficiência nas fazendas de milho foram detectados por meio do modelo de regressão Tobit. De acordo com os resultados da pesquisa, os níveis médios de TE das fazendas de milho na área de pesquisa sob as condições de retorno variável à escala são encontrados em 0,887 (111 fazendas). Esses resultados sugerem que, se as fazendas reduzirem o uso de insumos em 11,3% em média, podem atingir o mesmo nível de produção e alcançar eficiência técnica plena. A fonte mais ineficaz em termos de desempenho das fazendas são os gastos com máquinas, com 68,2% do uso excedente continuado com o uso de mão de obra. Nesse sentido, a mecanização, a modernização, a educação e o treinamento da força de trabalho e o uso de fertilizantes e pesticidas mais sensíveis podem ser sugeridos para aumentar a eficiência das fazendas de milho. Os resultados do modelo de regressão Tobit indicam que fatores como experiência, escolaridade, número de tratores e tamanho da área irrigada influenciaram positivamente no TE, enquanto o tamanho da família na cultura do milho tem efeito negativo.*
Palavras-chave: *eficiência técnica, fazendas de milho, análise Envoltória de Dados, Modelo Tobit.*

INTRODUCTION

Although, developments in the agricultural sector affected all agricultural products, they were more effective on industrial crops such as corn, sugar beet, soybean, and sunflower. Corn production in the world and Turkey have increased significantly for 40 years. Since the 1970s, corn has had a production value of twice the average production amount in Turkey. There are several reasons for the productivity changes like increases in yield provided by the hybrid seed in Turkey. Later, new techniques applied in increasing production depending on demand, increase in production areas and policy changes contributed to the increase in production value in Turkey. In addition to all these changes, the population growth in the world, the limited availability of agricultural land, the realization of raw material supply from the agricultural sector in the industrial production areas and the continuous increase in the demand for corn

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in the industrial sector necessitate the efficiency increase on corn production (BAYRAMOĞLU & BOZDEMIR, 2018).

Corn is one of the most significant cereals in the world depending on its multipurpose use like human nutrition, producing feed grain, fuel ethanol, starch and artificial sweeteners. The production patterns of corn, rice and wheat are 1 billion tonnes,741 million tons and 729 million tons, respectively (FAO, 2016). Regarding planting area, 7.7 million ha. of land is utilized for wheat production (21.5 million tons) which takes first place in Turkey and is followed by barley and corn with an area of 2.72 million ha. and 639084 ha., respectively.

When the production and cost data for corn agriculture in Turkey are examined; It is seen that the yield is 2159 kg/da, the total production value is 152.92 $/da, and the total production costs are 99.28 $/da. However, while the net income per decare per unit area is $53.64, the unit cost is $0.05/kg. The share of variable costs in total production costs in corn production is 83.68% and the share of fixed costs is 16.32%. Conversely, land rent has a share of 13.81% in total expenses, fuel 28.36%, electricity 0.62%, fertilizer 12.12%, pesticides 2.58%, seeds 10.71%, water fee 2.84%, labor 17.94%, machinery repair-maintenance depreciation 3.78% and other items have a share of 7.24% (TOB, 2020).

According to TURKSTAT statistics (2018) on crop product balance, corn sufficiency is 73.3% in Turkey. It is observed that Turkey is a corn importer due to the increase in the demand for feed raw materials in parallel with the production of eggs and poultry and the increase in the number of cattle in the last years. Corn consumption in Turkey is predicted to be between 7.5 and 8 million tons in 2019, and the domestic need increases depending on the growth in the poultry industry (TURKSTAT, 2018). Adana is the city where corn is produced the most as the first product in Turkey with 82000 tons and it realizes approximately 13% of the total production. In Adana, Yüreğir, Seyhan and Ceyhan districts are the regions where corn cultivation is done most intensively (TURKSTAT, 2020).

This study investigated the efficiency calculation of input usage in corn production as well as the determinants of the inefficiency using DEA and Tobit regression models. As a result, it will be able to determine how well the sector or unit of production performs in terms of resource utilization (DJOKOTO et al., 2016).

Literature Background

There are various studies on the production efficiency of corn worldwide in Turkey. In the study conducted by DOĞAN & KULEKÇİ (2020) in 110 farms to determine the efficiency of the corn-producing farm in Iğdır province and the factors affecting the efficiency, the technical efficiency value was 0.937 under the assumption of returns to scale. Accordingly, farms can reach the same production value by reducing their input costs by approximately 6.3%. In addition, according to the fractional logit model they applied, the only factor affecting the efficiency was determined as the age of the operator. It has been determined that when the age of the operator increases by 1 year, inefficiency increases by 0.88%. In the research conducted by PAKSOY & ORTASÖZ (2018) for the economic analysis of corn production activity, covering 55 enterprises, the share of variable costs for corn production in enterprises was calculated as 81.80% and the share of fixed costs as 18.20%. In addition, it was determined that fertilization and labor took the biggest share in variable costs, followed by seed, irrigation and labor from other variable costs. In their studies KOÇ et al. (2011) to determine technical efficiency in maize growing farms in Turkey they applied a two-stage analysis of DEA and Tobit regression models to the data obtained from 89 maize farms. They calculated the technical efficiency scores as 81%. The greatest excess input use was reported in fertilizers, machinery and labor use and harvesting area found as the unique factor that effects the inefficiency situations in maize farming. BAHTA et al. (2020) studied technical efficiency in Zimbabwe maize farming and reported that the mean technical efficiency of the respondents was 77%. Thus, there is a potential for respondents to increase their efficiency by 23% if they use existing farm resources efficiently. Besides, human capital, compliance with best management practices, and participatory extension service were significant and associated with enhancing technical efficiency. However, financial characteristics (lack of access to credit and lack of off-farm income) and owning farm equipment were associated with a decrease of production and respondents' technical efficiencies. According to the results of a study conducted by ABDULAI et al. (2018a) in northern Ghana with 360 maize farmers, technical efficiency in maize production was calculated as 77% which showed that 23% of potential maize output is lost to inefficiency. Farmers with many years of experience in maize production were more technically efficient, and opportunities such as family farms and farmer field schools, which bring less experienced farmers together with more experienced ones to tap into the accumulated knowledge of the latter, which would improve maize production. ABBAS et al. (2020) investigated energy efficiency (fertilizer, diesel fuel, irrigation water and chemicals) in maize agriculture in Pakistan using DEA model and reported the efficiency score as 59.67% which described the inadequacies of resource utilization in the selected area of study and the plausible high potential for resource conservation. Results of the study suggested resource conservation measures through better agricultural management practices, and production methods and extension activities are required to improve the efficiency of energy consumption in maize production of Pakistan. BANAEIAN & ZANGENEH (2011) studied energy efficiency determination during Iran's corn production, qualitative analysis of energy flow as well as DEA. They put forward that the energy consumed for corn production increased together with the energy obtained from corn production between 2001 and 2007, and while calculating the efficiency relationship between the energy consumed and the energy obtained by DEA. In a similar study, LI et al. (2011) calculated the production efficiency of corn by using DEA in the Hebei province of China. In their study, they used two outputs andsix inputs based on agricultural product research. Production efficiency in seven districts can only be increased by increasing the share of agriculture; In the remaining 15 districts, they concluded that production efficiency could be increased by reducing inputs or limiting the share of agriculture. LI & ZHU (2018) used the HP (High-Pass) filter to improve the production efficiency of maize and the Malmquist Index Method for analyzing the changes of TFP (Total Factor Productivity) of maize in 18 cities in Henan. They founded that the research and development level of advanced technology of maize production in Henan Province has been improved to some extent in recent years; the advanced technology in various regions has not been fully promoted and utilized; there is a certain degree of relaxation in the input of various elements of maize.

MATERIALS AND METHODS

Material

In this study, both primary and secondary data were used to calculate the efficiencies of corn production in Adana province. As primary data, survey data were collected from 111 corn producers by using face-to-face survey method in three districts of Adana province for the 2019 cultivation season. The surveys were applied in villages of Seyhan, Yüreğir and Ceyhan towns. Besides, some statistics, thesis, publications, and reports related to corn farms were used as secondary data as supportive of the primary data. Those statistics were classified and presented as tables and graphs. Also, data from FAO, TURKSTAT, and the Ministry of Agriculture and Forestry were used as secondary data.

The sample size of the study was calculated with the help of the formula given below.

$$n = \frac{p.(1-p)}{\left(e/Z\right)^2}$$

In the formula, n is the sample size, p is the frequency of the observed event, e is the margin of error, and z is the confidence interval. Based on the highest value of p (1-p), the margin of error was accepted as e = 5% and the confidence interval was 95%, and the result was 110 farms.

The data constitute of inputs used per decare of wheat production including seed ($/da.), fertilizer ($/da.), pesticides ($/da.), labor ($/da.), mechanization (min/da.) and fuel (Lt/da.) while the gross production of wheat ($/da) was the single output. As a result of the interviews with field crop experts, it was determined that the inputs used in the analysis included all the inputs used in corn production.

Methodology

To achieve profitability conditions in agricultural production, it is important to maximize efficiency in farm levels (KELLY et al., 2012). As a result, for both theorists and agro-policymakers, assessing the success of decision-making units (DMUs) starts with measuring efficiency as the first step toward progress in the agriculture industry (FARRELL, 1957).

For investigating corn production efficiency in Turkey, Data Envelopment Analysis (DEA) was used which is the most relevant tool for allocating resources and determining the relative efficiency of DMUs (AL-MEZEINI et al., 2020; BANDBAFHA et al., 2018; NANDY & SINGH, 2020).

DEA is a mathematical linear programming method used to estimate the comparative efficiency of homogeneous organizational units, called DMUs that use the same inputs to produce the same outputs (LI & ZHU 2018; MARDANI et al., 2017). It is a multi-factor efficiency analysis tool that estimates the relative effectiveness of multiple inputs and outputs comparing the success of similar organizations or products such as nations and , companies (LI & ZHU 2018; MARDANI et al., 2017; SU & FAN, 2020). DEA methods are often used in economics to solve problems of cost, gain, and profit, as well as to find the distribution of effectiveness, estimate technological development and find the distribution of effectiveness (SU & FAN, 2020). DEA model is a common method for assessing the agricultural sector and determining how efficiently a farmer can achieve a certain amount of production by comparing the levels of available input capital to those of other farmers (EXPÓSITO & VELASCO, 2020; NANDY & SINGH, 2020).

DEA find a best-practice frontier of efficient Decision-Making Units (DMUs) that envelops all inefficient DMUs. The distance to the boundary can be used to assign an efficiency value to each DMU. The DEA model is concerned with calculating a technical efficiency ranking, which implies that resource allocation is not a factor (KOHL et al., 2019).

The use of a non-parametric DEA method is becoming increasingly common for a variety of reasons. First, it does not involve any assumptions about the functional form of the manufacturing technology or price details. Second, DEA does not need aggregation for multiple inputs and outputs. Third, since DEA is based on linear programming techniques, each company's "be--hst practice" can be identified. Finally, its ability to decompose productivity growth into two components: technical efficiency improvements over time and technical change (BAGCHI et al., 2019).

The DEA models that are mostly used are Banker, Charnes, Cooper (BCC) and Charnes, Cooper, Rhodes (CCR). The original assumptions of the BCC and CCR models are the variable returns to scale model (VRS) and the constant returns to scale model (CRS), and the methods of measurement are input-oriented and output-oriented, respectively (LI & ZHU 2018). The envelopment in CCR is constant returns to scale meaning that a proportional increase in inputs results in a proportionate increase in outputs (TOLOO & NALCHIGAR, 2009).

Assuming that there are N DMUs, each with K inputs and M outputs, an input-oriented BBC model is briefly introduced as follows: (SANGUN et al., 2018).

$\text{Min}_{0,\lambda}\theta$ subject to

$-\quad y_i + Y\lambda \geq 0$

$\theta X_i - X\lambda \geq 0$

$N1'\lambda = 1$

$\Lambda \geq 0$

Where,

X_i : Input vector of the decision-making units to be analyzed

y_i : Output vector of the decision-making units to be analyzed

θ : Efficiency score of the i^{th} unit

λ : N x 1 vector of constants

Y : Output matrix

X : Input matrix

To estimate DEA efficiency scores, DEAP software version 2.1 by COELLI (2005) was used in the study and these scores were calculated under constant and variable return to scale assumptions (CRS and VRS). In this study, the equation represents the cost minimization under variable returns-to-scale (VRS) technology. VRS means that output increases in proportion to changes in all inputs (best input combination). It is also known as a measure of overall technical efficiency helping to determine inefficiency due to the input/output configuration as well as the size of farms. In DEA, overall technical efficiency scores have been calculated into two components (TE scores under VRS). This components allowed an insight into the source of inefficiencies: pure technical efficiency (PTE), which reflects the ability of corn farms to obtain maximal outputs at an optimal scale and scale efficiency (SE), reflecting the distance of an observed corn farm from the most productive scale size.

Also, scale efficiency equals the ratio of TE CRS to TE VRS. The measure of SE provides the ability of the management to choose the optimum size of resources. Production is scaled efficiently if SE = 1.0, or if the TE CRS = TE VRS. The cause of scale inefficiency can be seen in two forms: decreasing returns-to-scale (DRS) and increasing returns-to-scale (IRS). In this study, to evaluate the efficiency scores of the corn farms in Adana province of Turkey, one output (production value of corn) and five inputs (fertilizer, seed, labor, machine and pesticide) were evaluated in the efficiency model.

Conversely, the Tobit regression also known as the truncated or censored regression model was used to model the efficiency level obtained from the first stage on factors that could influence the efficiency score. James Tobin (1958) first proposed the Tobit model to explain the relationship between a non-negative dependent variable y and independent variables. It is still commonly used in efficiency analysis to characterize the factors correlated with efficiency ratings. The dependent variables in this study were the TE scores obtained from the DEA, which ranged from 0 to 1, and the independent variables were farm-specific attributes. In this context; although,+ there are many farm characteristics, experience, education, family size, numbers of the tractor, irrigation frequency, which have a high potential to affect the efficiency status as a result of interviews with farmers, they were accepted as independent variables.

The model can be represented as follows:

$y^* = X\beta + \varepsilon$,

Where y^* donates the technical efficiency situation of the corn farms, X is the explanatory variable and β is the unknown parameter.

$y = y^*$ if $y^* \geq 0$,

$y = 0$ if $y^* < 0$,

with $\varepsilon \sim N(0, \sigma2)$

When the value $y^* \geq 0$, it takes the actual observation; when $y^* < 0$, the observation is truncated to 0 (SU & FAN, 2020).

Variables used in Tobit regrade analysis include numerical-numerical (experience, family size, etc.) and non-numerical categorical variables (education). Descriptive statistics of the numerical variables used in the analysis are given in table 1.

RESULTS

In table 2, while the annual average production value of corn per decare is calculated as 127.03 USD/decare. Within these usage on average, amount of Nitrogen was 22.38 kg/decare, Phosphorous was 20.25 and Potassium was 5.3, respectively.It was 2.54 kg/decare for seed on average, 0.53 hour/decare for labor, 3.28 hour/decare for machine power and 3.23 USD/decare for pesticide. Besides, table 2 shows us variation coefficients. As it is seen on the table, expenditures for machine and labor use have the highest variation coefficient values. This situation indicates that the production process for corn is not properly managed and that inputs are not used correctly.

The DEA results for the efficiency status performances in corn farms are given in table 3. According to the input-based DEA results, the average technical efficiency of corn farms under constant returns to scale (CRS) is 0.749 while the average technical efficiency under variable returns to scale (VRS) is 0.887 and the scale efficiency (SE) is determined as 0.847. Besides, results of frequency distributions of the scores of DEA analysis indicates that the number of full efficient corn farms under the variable returns to scale (VRS) is 57, while the number of corn farms with fully efficiency under constant returns to scale (CRS) is 20 and, the number of scale efficient (SE) corn farms is 23. Under the CRS conditions, the number of corn farms with activity scores in the range of 0.60-0.69 activity score is 26, while under VRS conditions for numbers of corn farms are 8 and under SE conditions, 13. These numbers were calculated for efficiency scores for range 0.70-0.79 are 21, 19 and 19, respectively.

These results suggested that corn farms can use inputs more efficiently in corn farming activities, by increasing the efficiency of resource use. It sounds reasonable that if farms reduce their input usage by an average of 11.3%, they can achieve the same corn production performance. Besides, it is determined from the survey that 39% of the farms investigated are in the increasing return to scale position, the other 21 of them are in the decreasing return to scale position and only 10 (16%) were in the full efficiency limit.

When corn farm activities are analyzed, it has been determined that the main factors that bring inefficiency are machine use and labor force. Besides, corn farms are not able to provide the appropriate input composition, and this causes inefficient use of inputs. Excess input use of corn farms is given in table 4.

Table 1 - Variables used in Tobit Regression.

Variables	Mean	Min.	Max.	Std. Dev.
Experience (year)	36.00	5.00	65.00	12.80
Education (high school and above=1; others=0)	0.40	0.00	1.00	0.50
Family Size (persons)	5.10	1.00	20.00	2.80
Numbers of Tractor (number)	2.60	0.00	12.00	2.30
Numbers of Irrigation (number)	5.70	2.00	10.00	1.60

Table 2 - Data for input and output variables.

Variables	Mean	Min.	Max.	Std. Dev.	Coeff. of Var.
---Output---					
Production value (USD/decare)	127.03	39.35	195.52	22.94	0.18
---Inputs---					
Fertilizer (kg/decare)					
Nitrogen (N)	22.38	4.20	44.10	6.68	29.8
Phosphorous (P)	20.25	3.80	39.90	6.04	29.6
Potassium (K)	5.33	1.00	10.50	1.59	28.9
Seed (kg/decare)	2.54	1.50	5.50	0.90	35.6
Labor (hour/decare)	0.53	0.01	5.10	0.72	136.5
Machine (hour/decare)	3.28	0.01	63.93	9.41	287.2
Pesticide (USD/decare)	3.23	0.001	45.40	6.47	2.00

1 USA dolar=8.26 TRY.

According to the results of the input use analysis (Table 4), it is obtained that the most ineffective source in terms of farms performance is machine expenditures with 68.2%. Besides, other important sources of ineffectiveness are expenditures on the labor force with 50.8% and pesticide with 27.4%. It was also found that there is excessive input use in fertilizer with 20.7% and seed with 13.7%, respectively.

Determinants of Technical Efficiency

To determine the source of inefficiency in the performance of corn farms, regression analysis was performed between the efficiency scores

Table 3 - Distribution of the efficiency scores of the surveyed farms.

Efficiency Scores	CRS	VRS	SE
1.00	20	57	23
0.90–0.99	9	11	25
0.80–0.89	14	8	25
0.70–0.79	21	19	19
0.60–0.69	26	8	13
0.50–0.59	14	6	5
0.40–0.49	2	1	0
< 0.40	5	1	1
Mean	0.749	0.887	0.847
Minimum	0.228	0.344	0.292
Maximum	1.000	1.000	1.000
Standard deviation	0.182	0.158	0.144

CRS: Constant Returns to Scale, VRS: Variable Returns to Scale, SE: Scale Efficiency.

Table 4 - Input slacks and the number of farms using excess inputs.

Inputs	Numbers of Farms (Units)	Average Slack	Average Input Usage	Excess Input Use (%)
Fertilizer (N, P, K)	57	3.32	15.98	20.7
Seed (kg/decare)	34	0.35	2.54	13.7
Labor Force (Hour/decare)	56	0.27	0.53	50.8
Machine (Hour/decare)	53	2.23	3.28	68.2
Pesticide (USD/decare)	34	0.88	3.23	27.4

1 USA dolar=8.26 TRY.

obtained from DEA analysis under Variable Returns to Scale and the socio-economic and demographic characteristics of the corn farmers. For this purpose, a two-tailed Tobit model, since efficiency scores are between 0 and 1, was applied (RAY, 2004). In this model, education (high school and above=1; others=0) experience in agricultural production, family size, the number of tractors owned and the number of irrigations. In the analyzes between the efficiency score and the socio-economic characteristics of the corn, producers were included in the analysis. Analysis results are given in table 5.

When the relationship between the efficiency scores as a result of the analysis and the socio-economic and demographic of corn farmers is examined by Tobit analysis; No statistically significant difference was reported between efficiency level and variables of experience, education, family size and the number of irrigations. Besides, a statistically significant relationship was reported between the variable number of tractors and efficiency level.

According to the findings as a result of the analysis (Table 5); There is a statistically significant and positive relationship between the number of tractors owned by corn farms and their production performance efficiency ($P < 0.05$). Results determined that corn farms with more tractors work more effectively and use their resources more effectively. KOUSER & MUSHTAQ, (2007) reported the same result that tractor (mechanization) use could significantly contribute to improve farmers' technical efficiency in rice production in Pakistan. In their studies, SADIQ et al., (2009) also reported a positive relationship between tractor use and corn production efficiency in various zones of Azad Jammu and Kashmir with the survey conducted to 130 farms. Besides, GUNDUZ et al., (2011) reported that tractor ownership has a positive effect on economic efficiency in apricot farming in Turkey. However, ABDULAI et al.,

Table 5 - Results of the Tobit model for efficiency scores.

Variables	Coefficients	Std. Error	z-Statistic	S.E.
Constant	0.809	0.088	9.142.382	0.000*
Experience (year)	0.001	0.001	0.646604	0.518
Education (high school and above=1; others=0)	0.002	0.030	0.053198	0.958
Family Size (persons)	-0,004	0,006	-0.781448	0,435
Numbers of Tractor (unit)	0,015	0,007	2.258.146	0,024**
Numbers of Irrigation (unit)	0,005	0,009	0.594787	0,552
Avg.Log likelihood: 0.450765 prob>F: 0.0000				

*: P<0.01; **: P<0.05

(2018) a reached that agricultural mechanization did not have positive effects on the technical efficiency of maize production in northern Ghana. Controversially, TUN & KANG, (2015) stated that the level of farm mechanization has a significant negative effect on the technical inefficiency of rice production. In this context, it can be said that the level of agricultural mechanization is an important variable in the region, and the creation of suitable credit or grant conditions for corn producers to supply new machinery and equipment or to renew their existing equipment will bring beneficial results for corn production in the region. Besides; although, no statistically significant relationship was reported between the family size (persons) and their production performance efficiency ($P < 0.01$), a negative relationship between family size and efficiency level cause over labor use. That iswhy it causes high labor expenditures, family size has negative effects on efficiency scores and is one of the important reasons for inefficiency in corn farms.

In this context, it can be stated that the level of agricultural mechanization is an important variable in the region, and the creation of suitable credit or grant conditions for corn producers to supply new machinery and equipment or to renew their existing equipment will bring beneficial results for corn production in the region.

CONCLUSION

The global need for corn will increase in the coming years because the consumption of poultry meat and eggs increase. Therefore, it is predicted that the upward trend in corn prices, which is an average of $170 per ton. Thus, specific intervention policies need to be designed and targeted at specific types of products in Turkey. Besides, increasing the production of such products, efficiencies of agricultural farming became important for sustainable and efficient natural resource use.

This paper estimated the technical and scale efficiency of corn farms in Adana province and established the factors affecting technical efficiency. For this reason, two-step methodology. DEA method to determine the efficiency of corn farms and Tobit regression model were used to explain variations inefficiencies between corn farms.

The empirical results provide evidence that technical inefficiency in corn production exists among the sample corn farms. The parameter estimates showed that factors such as family size negatively influenced technical efficiency, whereas the experience of farmers, education, numbers of tractors and numbers of irrigation showed a positive relationship with efficiency.

As a result of the unfavorable operating structure in Turkey, the annual tractors use is limited to 500-600 hours. Even though the longest tractor life in Turkey is 24 years, 46% of the existing tractor park consists of tractors that have completed their mechanical life. Conversely, when the situation of tractors aged 25 and over in Turkey is examined, it was seen that approximately 51% of the existing tractors are aged 40 and over. No matter how well maintained these tractors are, they are unlikely to be used efficiently, but they cause various problems such as maintenance and repair costs, excessive fuel consumption, job losses, accident and life safety risks due to frequent breakdowns. In addition, there are 19 provinces in Turkey with above-average use of tractors and the area where this research was conducted is among these provinces (MAF, 2018). While excessive use of tractors is a common factor in the region, it causes job losses due to maintenance and repair costs, excessive fuel consumption, and frequent breakdowns, leading to inefficiency in terms of agricultural enterprises. In this context, there is a need to modernize the level of mechanization in agricultural enterprises in the region.

Also according to the results, excessive use of machinery comes first among the reasons for ineffectiveness. The old machine park (tractor and equipment) in the region causes higher machine variable costs and increased depreciation costs. In this context, it will be appropriate for the region to develop financing models that require the replacement or renewal of old model machines with new generation machines. In addition, the inclusion of measures for the creation of new machinery parks in the rural development policies and grant programs implemented by the government will be among the factors that will directly affect the increase in the efficiency level of corn production in the region and the use of excessive machine power.

The findings of this research have important policy consequences. There is a suggestion from the technical efficiency estimates that the majority of the sampled corn farms either do not have the best technology available or are not utilizing the available technology efficiently. Any policy intervention directed at bridging this technology gap or misuse of existing technology would have the effect of increasing the overall technical efficiency of corn farms in Adana province.

It is a fact that agricultural land in Turkey is extremely fragmented and there are considerable distances among these parts. This situation may cause the inefficiency of agricultural farms. Therefore, corn farming in larger lands with land consolidation works will contribute positively to productivity.

Also, it is worth noting that fertilizer and seed use is not efficient. It sounds reasonable that if farms reduce their input usage by an average of 11.3%, they can achieve the same corn production performance.

In general, if agricultural productivity can be increased through an increase in technical efficiency, resources can be freed from the agricultural sector for industrial sector growth in line with government industrialization objectives.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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