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Original Article

Farm-Level Efficiency Analysis of Confectionery Sunflower Production in The Pasin Plain: A Data Envelopment Approach

Emirhan Yılmaz Kavran[1]✉, Vedat Dağdemir[2]✉

[1]Şanlıurfa, Harran University, Faculty of Agriculture, Department of Agricultural Economics, Şanlıurfa, TÜRKİYE
[2]Erzurum, Atatürk University, Faculty of Agriculture, Department of Agricultural Economics, Erzurum, TÜRKİYE

[1]https://orcid.org/0000-0003-4759-9893, [2]https://orcid.org/0000-0002-2293-9460

ABSTRACT

This study evaluated the technical, allocative, and economic efficiency levels of 140 confectionery sunflower farms in the Pasin Plain, Erzurum province, using Data Envelopment Analysis (DEA). Primary data were collected through face-to-face surveys during the 2022 production season. The bootstrapped DEA technique was employed under both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions. According to the findings, the farms classical technical efficiency score was 0.88, whilst bootstrapped technical efficiency score was 0.83, their allocative efficiency score was 0.82, and their economic efficiency score was 0.72. These results indicate that farms manage their production processes relatively efficiently with existing technology and resources (17.00% savings potential in pure technical efficiency), but there are significant areas for improvement in selecting the optimal input mix at correct prices (18.00% savings potential in allocative efficiency) and in overall cost performance (28.00% savings potential in economic efficiency). Furthermore, approximately 24.00 % of the overall inefficiency was attributed to scale inefficiency. The study presents concrete policy recommendations focused on cost management and market analysis in agricultural extension services. The recommendations include encouraging land consolidation and the formation of cooperatives, promoting the widespread use of existing digital applications among producers, and providing low-interest loan opportunities for small-scale businesses. These findings provide a solid scientific foundation for developing strategies to enhance the sustainability and economic efficiency of sunflower seed production in the region.

Key words: Confectionery sunflower, efficiency analysis, data envelopment analysis (dea), pasin plain.

Pasin Ovası'nda Çerezlik Ayçiçeği Üreticilerinin Etkinlik Analizi: Veri Zarflama Yaklaşımı

ÖZ

Bu çalışma, Erzurum iline bağlı Pasin Ovası'nda çerezlik ayçiçeği üretimi yapan 140 işletmenin teknik, tahsis ve ekonomik etkinlik düzeylerini Veri Zarflama Analizi (VZA) yöntemiyle değerlendirmeyi amaçlamıştır. Araştırmanın birincil verileri, 2022 üretim döneminde yüz yüze anket yöntemiyle toplanmıştır. Analizlerde, Ölçeğe Göre Sabit Getiri (CRS) ve Ölçeğe Göre Değişken Getiri (VRS) varsayımları altında teknik etkinliğin ölçümünde Bootstraplı DEA tekniği kullanılmıştır. Bulgulara göre, işletmelerin klasik teknik etkinlik ortalaması 0.88 iken bootsraplı teknik ortalaması 0.83, tahsis etkinlik ortalaması 0.82 ve ekonomik etkinlik ortalaması 0.72 olarak belirlenmiştir. Bu sonuçlar, üreticilerin mevcut teknoloji ve kaynaklarla üretim süreçlerini nispeten etkin yönettiklerini (saf teknik etkinlikte %17.00 tasarruf potansiyeli), ancak girdi bileşimini doğru fiyatlarla seçme konusunda (tahsis etkinlikte %18.00 tasarruf potansiyeli) ve genel maliyet performansında (ekonomik etkinlikte %28.00 tasarruf potansiyeli) iyileştirme alanları olduğunu göstermektedir. Ayrıca, işletmelerin genel etkinsizliğinin yaklaşık %24.00'ünün ölçek etkinsizliğinden kaynaklandığı tespit edilmiştir. Çalışma, tarımsal yayım hizmetlerinde maliyet yönetimi ve pazar analizi odaklı somut politika önerileri sunmaktadır. Öneriler arasında, arazi toplulaştırmasının ve kooperatifleşmenin teşvik edilmesi, üreticiler için mevcut dijital uygulamaların kullanımının yaygınlaştırılması ve küçük ölçekli işletmelere düşük faizli kredi imkanlarının sağlanması yer

almaktadır. Bu bulgular, bölgedeki çerezlik ayçiçeği üretiminin sürdürülebilirliğini ve ekonomik verimliliğini artıracak stratejilerin geliştirilmesi için sağlam bir bilimsel temel sağlamaktadır.

Anahtar kelimeler: Çerezlik ayçiçeği, etkinlik analizi, veri zarflama analizi (vza), pasin ovası

INTRODUCTION

Agriculture is an important sector in Turkey due to its functions and scale (Demir et al., 2023). The contribution of agriculture to the national economy has a significant share in developing countries such as Türkiye (Palabicak and Ödemis, 2026). Global population growth and pressure on natural resources have made productivity and sustainability primary priorities in the agricultural sector. Efficiency can be defined as achieving a given output level with minimal input use or maximizing output with available resources. It is one of the most critical determinants of the profitability and economic sustainability of agricultural enterprises. In this context, Farrell (1957) was the first to measure enterprise performance, laying the foundation for modern efficiency analysis as linear programming techniques developed. In Türkiye efficiency analyses have gained importance since the 2000s for the sustainability of agricultural enterprises (Özden, 2017; Savaş and Işın, 2024).

Agricultural efficiency is examined in three subcomponents: technical efficiency, which refers to obtaining a certain output with the least possible input, allocative efficiency, which measures the ability to choose the lowest-cost input combination under current input prices and economic efficiency, which reflects the overall cost performance, which is the combination of these two (Coelli et al., 2005). Agricultural economics studies analyze these activities and aim to achieve current production levels with the least possible input or at the lowest cost (Doll and Orazem, 2005; Gündüz et al., 2011).

Sunflower cultivation, which stands out globally for its production, is closely related to the principles of this study. Sunflowers are grown in two categories: for confectionery and for oil (Hladni and Miladinovic, 2019). While Russia, Ukraine, and European Union countries lead in the production of oilseed sunflowers, Argentina and China lead in the production of confectionery sunflowers (Liuxi Yi et al., 2025). While oilseeds account for 90.00%–95.00% of global sunflower production, the share of sunflowers grown for confectionery is reported to be below 5.00% in some sources (Semerci and Durmuş, 2021) and below 10.00% in others (Hladni, 2016). China accounts for a large portion of this 10.00% share (Feng J. et al., 2022). In fact, the Food and Agriculture Organization (FAO) database does not distinguish between sunflowers grown for oil and those grown for confectionery. According to 2022 FAO data, Turkey ranks fourth in global sunflower production, accounting for 4.80% of the total production (53.09 million tons). The global average sunflower yield is 1,855.00 kg/ha, while Turkey's average yield is 2,602.90 kg/ha. Turkey's yield is above the global average. In global sunflower seed exports, Russia and Romania lead the way, while Bulgaria and Turkey are the leading importers (FAO, 2022).

Sunflower cultivation, which holds a prominent position in the Turkish economy, exhibits significant economic variations depending on its intended use. The market value of sunflower oil produced for industrial use depends on its oil content and is traded on national and international oilseed markets. Confectionery sunflowers, which are grown specifically for human consumption, are priced in the market based on physical characteristics such as seed size, shell color, uniformity, and overall appearance. It is primarily traded in the snack nut sector and local food markets. As a result, in recent years, the production of confectionery sunflower seeds in Turkey has shown a notable growth trend. In 2022, the total cultivated area of sunflowers was 980.972.20 hectares, and the production quantity was 2.550.000 tons. While confectionery sunflower constituted only 8.21% (80.456.50 hectare) of this cultivated area and 7.84% (200.000 tons) of the production quantity, by 2024, there was an increase of 47.65% in cultivated area and 70.00% in production quantity for confectionery sunflower, reaching 118.798.50 hectare and 340.000 tons, respectively (TÜİK, 2025). This remarkable growth, contrary to the contraction in oilseed sunflower production, highlights the market potential of confectionery sunflowers and its increasing economic importance for producers.

Looking at the geographical distribution of this production, the Central Anatolia Region (Konya, Kayseri, Aksaray, Sivas) leads, but Erzurum in the Eastern Anatolia Region also stands out as an important production center. According to 2024 data, Erzurum ranks fourth in production quantity and fifth in cultivated areas nationally. The determinant of this increase is the Pasin Plain, which alone accounts for more than 83.00% of the province's total production. The performance of producers in the Pasin Plain is strategically important for both regional development and national production targets. However, despite this quantitative increase in production, it remains unclear to what extent producers in the region can efficiently use their resources. Decreases in efficiency increase production costs, and in this context, input usage levels and the operator's production efficiency play a determining role. (Yeni and Dağdemir, 2022). While sustainable agriculture and

environmental awareness necessitate the optimal use of inputs such as chemical fertilizers and pesticides, adverse conditions can lead to environmental damage and reduced product quality (Sarı and Külekçi, 2024).

At this point, a significant gap is evident in the current scientific literature. Although there are numerous efficiency studies focusing on oilseed sunflower production (Grazhdaninova and Brock, 2004; Günden et al., 2006; Külekçi, 2010; Parlakay et al., 2016; Nijiku and Nyamsogoro, 2018; Semerci and Yurt, 2023; Semerci, 2024), confectionery sunflower production, which has different market dynamics, production structure, and economic returns, has largely remained outside these analyses. Despite the region's expanding production areas and economic importance, there is no scientific data on how efficiently confectionery sunflower producers use their resources, the extent of their inefficiencies, or the sources of these inefficiencies. The contribution of this study to the literature lies in the fact that it is the first to measure technical efficiency using the bootstrap method in confectionery sunflower production and to calculate the allocative and economic efficiency of farms. Accordingly, the study aims to measure the levels of technical, allocative, and economic efficiency among confectionery sunflower producers in the Pasin Plain and to identify the sources of scale inefficiency. The study aims to establish a scientific foundation for developing policy recommendations regarding the sustainability and profitability of agricultural production by demonstrating how efficiently producers in the region utilize their current resources.

MATERIALS AND METHODS

Research Area

Pasin Plain, located to the east of Erzurum province, extends to the east and west of the Erzurum-Kars plateau. Covering the districts of Pasinler, Köprüköy, and Horasan, and having an area of 700 km², the Pasin Plain constitutes the research area (Figure 1). The study focused on the districts of Pasinler and Köprüköy, where confectionery sunflower production is concentrated. These two districts are of strategic importance to the research, as they account for 77.76% of the total confectionery sunflower cultivated area, 83.36% of production, and 91.60% of the number of farms in Erzurum province. Horasan district was excluded from the study area due to its low production volume.

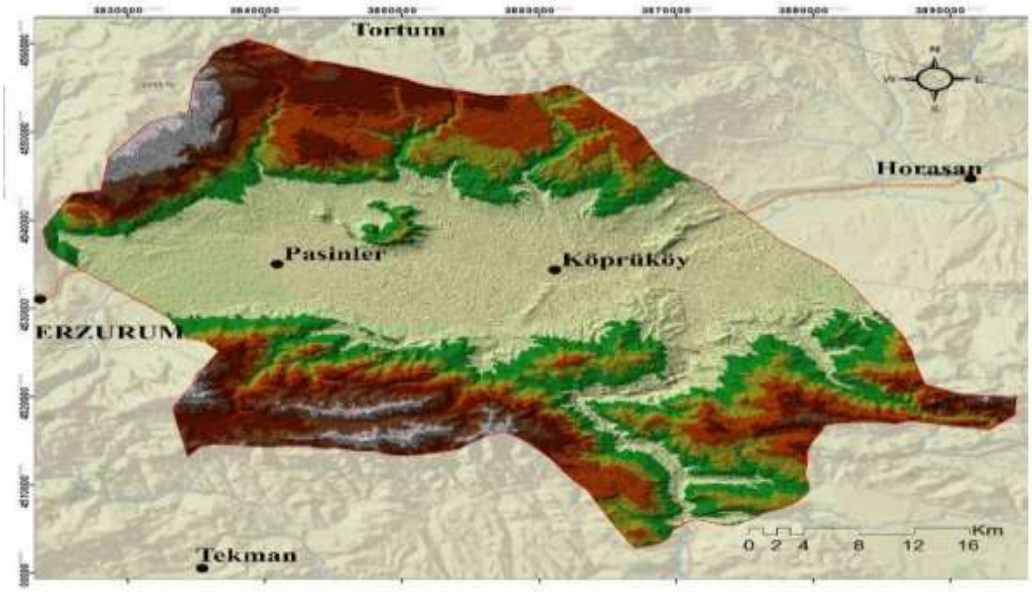

Figure 1. In the Pasin Plain, within the borders of Pasinler and Köprüköy (Koç and Yılmaz 2020).

Primary data for the research were collected through face-to-face surveys with confectionery sunflower producers in Pasinler and Köprüköy districts during the 2022 production season. Through these surveys, detailed information was obtained regarding the farms' production activities, input usage levels, and cost structures. Secondary data for the study were obtained from the Turkish Statistical Institute (TÜİK), the United Nations Food and Agriculture Organization (FAO), records of relevant Provincial and District Directorates of Agriculture and Forestry, and previously conducted scientific studies (theses, articles, reports) on the subject.

Sampling Method Used

It was determined that there are 2,816 farms registered in the Farmer Registration System (FRS) in the districts of Pasinler and Köprüköy within the study area. Farms with less than 1 decare that produce for household consumption were excluded from the population because they were deemed to have no economic value, and farms with more than 50 decares were excluded because they were expected to compromise the homogeneity of the sample and increase variance, thus, a total of 2,581 agricultural farms growing sunflowers for confectionery production on plots ranging from 1 to 50 decares were included in the analysis.

In agricultural economics studies, random sampling is much more preferred than other sampling methods. The advantage of the random sampling method is that the statistics obtained from the sample can represent the population parameters within a certain confidence interval and with a known margin of error (Newbold, 1995; Tuvanç and Dağdemir, 2009; Kumbasaroğlu and Dağdemir, 2011).

The sample size was calculated using Equation 1 under simple random sampling, assuming a 90% confidence level and a 10% margin of error (Yamane, 2001; Tuvanç and Dağdemir, 2009).

$$n = \frac{N*S^2*z^2}{(N-1)*d^2+S^2*z^2} = \frac{2581*0,7555*2,706}{(2581-1)*0.01383+0.755*2.706} = 140 \qquad \text{(Eq.1)}$$

In the equation: n = Sample size, N = Total number of farms in the population (2.581), S^2 = Population variance (0.7555), z = Confidence level coefficient (1.645), d = Acceptable margin of error (1,176*0,10= 0.1176), d^2 =0.01383.

As a result of Equation 1, the sample size was determined as 140 farms. Considering the districts' weights in the main population, 100 (71.43%) surveys were conducted in Pasinler and 40 (28.57%) in the Köprüköy district.

Efficiency Analysis

Efficiency refers to the degree to which activities are carried out in the most appropriate manner within a production process that involves both inputs and outputs. Efficiency measurement is performed using a ratio that indicates the extent to which actual performance approaches the theoretical target level; a value of 1 (or 100%) indicates full efficiency. An efficiency value below 1 indicates non efficiency, while it cannot exceed 1 (Aşkan, 2023). Efficiency analyses can be conducted using two distinct approaches: input-oriented and output-oriented. In agricultural production, farmers have greater control over inputs than over outputs (Işgın et al., 2020; Gündüz et al., 2011; Hajime et al., 2016). Consequently, Farrell (1957) approached technical efficiency from the input perspective, focusing on achieving a specific output level using the minimum possible inputs. Indeed, it is evident that the risks and uncertainties inherent in the production process lead producers to intervene in inputs, and that input-oriented efficiency analysis is more widely used in the agricultural sector (Bravo, U., and Pinheiro, 1993).

To assess the efficiency of the farms using the collected data, Data Envelopment Analysis (DEA), a nonparametric method, was employed. DEA measures the relative performance of decision-making units that produce similar outputs using similar inputs, with a linear programming-based approach (Charnes, Cooper, and Rhodes, 1978). The ability of this method to handle datasets with multiple inputs and outputs, and to do so without requiring a prior assumption about the production function, is the main reason for its widespread use in agricultural economics studies (Temur and Bakırcı, 2008; Özden, 2010). Producers target high profits. To achieve this goal, they either try to achieve the highest output with a certain level of input usage or try to produce a certain level of output with the least input usage level. Data Envelopment Analysis is one of the methods used to determine the extent to which producers are successful in achieving their goals. DEA is one of the methods used to measure input usage efficiency (Parlakay and Çimrin, 2021).

In parametric methods, the production process is expressed by means of a mathematical function. Within the scope of this function, it is envisaged that the relationship between inputs and outputs can be established and that the relevant parameters can be estimated using econometric methods. With these methods (Cobb-Douglas and Translog), production curves are plotted based on predefined parameters. However, DEA is a non-parametric method used to determine the relative efficiency of decision-making units (DMUs) when their inputs and outputs are known and at the appropriate time (Kafi, A. et al., 2020). For this reason, there is no functional form. Production constraints are determined based on the observed data according to the DMU. In this context, the scope of the study has been defined according to decision-making units (DMUs) (Coelli et al., 2005; Mergoni A., 2025).

The analysis was conducted under both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions. Whilst the CRS model measures overall efficiency, the VRS model adjusts for scale effects by acknowledging that farms may operate at different scales. The ratio between the two models (CRS / VRS) reveals scale efficiency.

The relationship between the increase in production factors and the increase in total production determines the returns to scale (RTS). Returns to scale is measured as the ratio of the percentage change in total output to the percentage change in total inputs (RTS = % change in total output / % change in total inputs). When the increase in inputs is proportional to the increase in output, returns to scale are constant. If the rate of increase in output is lower than the rate of increase in inputs, this indicates diminishing returns to scale; if it is higher, it indicates increasing returns to scale. (Dinler and Zeynel, 2006).

In this study, a bootstrap DEA model for inputs was employed to enable confectionery sunflower producers to optimize their current production volumes and to determine the most suitable quantity and the lowest-cost input mix. For this reason, only the general formulation of this model is provided below.

$$\theta^* = Min\ \theta \quad \text{(Eq.2)}$$

$$\sum_{j=1}^{140} \lambda_j x_{ij} \leq \theta x_{i0}\ i = 1, \dots, 5; \quad \text{(Eq.3)}$$

$$\sum_{j=1}^{140} \lambda_j Y_j \geq Y_0 \quad \text{(Eq.4)}$$

$$\sum_{j=1}^{140} \lambda_j = 1 \quad \text{(Eq.5)}$$

$$Y_j \geq 0\ \ j = 1, \dots, 140; \quad \text{(Eq.6)}$$

θ It represents the technical efficiency score. Y_j represents the different decision units j that produce the output ($j = 1, \dots,$). In this study, the output considered was the quantity of confectionery sunflower production in a production period. x_{ij}represents the inputs used by each j decision unit. λ_j , j. It represents the intensity value determined by the decision-making unit.

Considering that standard DEA estimators can be biased and affected by random errors, the Bootstrapped DEA technique developed by Simar and Wilson (2000) was also preferred in this study, in addition to classical DEA analysis. In this study, bias correction was performed using 5,000 repetitions. The sufficiently large number of repetitions enhances the reliability of the estimated efficiency scores (Simar and Wilson, 2000). By creating 95.00% confidence intervals, it ensures that more robust and reliable efficiency scores are obtained. The specified confidence interval is not required, but the narrower the interval, the more robust the analysis will be (Tone, K. and Ouenniche, J., 2017). All analyses were carried out using R version 4.4.1.

In this study, the technical, allocative, and economic efficiencies of the farms were calculated separately, and the input and output variables used for each analysis are detailed in Table 1. The fact that the production areas of the farms included in the study range from 0.10 to 5.00 hectares, and that there are differences in scale between the farms, has the potential to distort the results of the scale effect. For this reason, the analysis was conducted on a per unit area basis.

Table 1. Variables taken into account in efficiency analysis.

Type of analysis	Output variable	İnput variable
Technical efficiency	Confectionery sunflower production amount (kg ha^{-1})	1. Seed quantity (kg ha^{-1}) 2. Amount of chemical fertilize (kg ha^{-1}) 3. Labor use (at ha^{-1}) 4. Number of irrigations (units year^{-1}) 5. Pesticide application rate (lt ha^{-1} or kg ha^{-1})
Economic efficiency	Confectionery sunflower production value (₺ ha^{-1})	1. Seed cost (₺ ha^{-1}) 2. Fertilizer cost (₺ ha^{-1}) 3. Labor cost (₺ ha^{-1}) 4. Irrigation cost (₺ ha^{-1}) 5. Pesticide cost (₺ ha^{-1})

In this study, calculations were performed based on an input-oriented (minimization) efficiency approach. Technical efficiency (TE) refers to the extent to which decision-making units (DMUs) can minimize the inputs used to achieve a given level of output, considering the existing technology and available resources. Allocative efficiency (AE) reflects the ability of farms to use inputs in optimal proportions, taking into account prevailing input prices, in order to minimize production costs for a given level of output. Economic efficiency (EE), on the other hand, represents a farm's ability to produce a given level of output at the minimum possible cost. Economic

efficiency is achieved when a farm is both technically and allocatively efficient and is calculated as the product of technical efficiency and allocative efficiency (EE = TE × AE) (Mohapatra, 2013; Yeni and Dağdemir, 2022).

RESULTS AND DISCUSSION

Basic descriptive statistics for the input and output variables included in the efficiency analysis are presented in Table 2.

Table 2. Descriptive statistics of variables

Variables	Mean	Std.dev.
Output		
Y: Confectionery sunflower production amount (kg ha^{-1})	2 700	92,38
Physical inputs (Technical efficiency)		
X_1: Labour (EİB ha^{-1})	26.00	20.20
X_2: chemical fertilizer (kg ha^{-1})	542.60	288.70
X_3: Seed (kg ha^{-1})	8.50	1.40
X_4: Number of irrigations (number)	3,03	1.15
X_5: Pesticide (lt ha^{-1})	5.50	2.80
Monetary inputs (Economic efficiency)		
X_6: Labor cost (₺ ha^{-1})	1 737.50	685.60
X_7: Fertilizer cost (₺ ha^{-1})	8 139.00	3 140.70
X_8: Seed cost (₺ ha^{-1})	3 400.00	706.20
X_9: Irrigation cost (₺ ha^{-1})	1 248.40	722.40
X_{10}: Pesticide cost (₺ ha^{-1})	4 125.00	2 515.10

An analysis of Table 2 shows that farms produce an average of 2,700 kg of sunflower seeds per hectare. Looking at physical inputs, it is evident that the highest input is the use of chemical fertilizers, followed by labor and pesticide use. When examining monetary inputs, it is observed that the highest cost item is chemical fertilizers, followed by pesticide and seed costs, significant differences were noted between farms in terms of production techniques and resource management.

Technical Efficiency Analysis

Technical efficiency scores, which measure how efficiently farms use their inputs under existing technology and production scale, were calculated under both CRS and VRS assumptions, using both classical (non-bootstrapped) and bias corrected (bootstrapped) methods. The results are summarized in Table 3.

Table 3. Comparison of technical efficiency scores in CRS and VRS

	Constant return to scale (CRS)						Variable return to scale (VRS)					
	Mean	**Std.dev.**	**Min.**	**Max.**	**Obs.**	**disc**	**Mean**	**Std.dev.**	**Min.**	**Max.**	**Obs.**	**disc**
eff	0.69	0.20	0,33	1,00	140	0	0,88	0,13	0,61	1,00	140	0
bias	0,06	0.05	0,02	0,24	140	0	0,05	0,03	0,01	0,12	140	0
bceff	0,63	0.17	0,31	0,99	140	0	0,83	0,12	0,59	0,99	140	0
LowerCI	0,53	0,15	0,30	0,90	140	0	0,78	0,11	0,56	0,97	140	0
UpperCI	0,65	0,19	0,33	0,99	140	0	0,87	0,13	0,60	1,00	140	0

Considering the bootstrapped values in the analysis, the average technical efficiency under the VRS assumption was 0.83. This result indicates that the surveyed farms use their inputs efficiently, at 83.00%. In other words, farms can reduce their current input levels by an average of 17.00% to maintain the same production quantity, owing to managerial skills and performance in production processes. This demonstrates that producers in the Pasin Plain have achieved a certain level of success in resource management. The traditional knowledge and experience of farmers in the region are effective in managing the production process, thereby maintaining relatively high technical efficiency. However, a remaining improvement potential of 17.00% underscores the

importance of enhancing agricultural practices, adopting modern technologies, and engaging scientific consultancy services.

To better observe the differentiation in efficiency levels of farms, the technical efficiency distribution scores for confectionery sunflower-producing farms are presented in Table 4.

Table 4. Technical efficiency distribution in enterprises producing confectionery sunflowers.

	Constant return to scale (CRS)		Variable return to scale (VRS)	
Efficiency range	**Non-bootstrapped**	**Bootstrapped**	**Non-bootstrapped**	**Bootstrapped**
eff<=0.40	9	11	0	0
0.40<eff<=0.50	17	28	0	0
0.50<eff<=0.60	34	31	0	3
0.60<eff<=0.70	19	17	18	23
0.70<eff<=0.80	13	20	23	31
0.80<eff<=0.90	19	29	29	36
0.90<eff<1	11	4	12	47
eff=1	18	0	58	0

As shown in Table 4, whilst the VRS analysis results without bootstrapping identified 58 farms as fully efficient (eff = 1), the fact that this figure drops to 0 according to the VRS analysis results with bootstrapping demonstrates the function of correcting bias in bootstrap VZA scores and enhancing statistical reliability. As bootstrapping estimates the statistical distribution of efficiency scores by resampling the original data set thousands of times, the traditional VZA indicates that the efficiency scores of the 58 fully efficient farms are statistically significantly different from 1, suggesting that these farms are not actually fully efficient (Simar, L., and Wilson, P., 1998; Simar, L., and Wilson, P., 2000).

Although the bootstrap analysis results in the VRS do not indicate the presence of fully efficient farms, it is observed that 33.60% of farms have an efficiency score between 0.90 and 1.00. This indicates that a significant portion of the farms use their resources efficiently. 59.30% of the farms have an efficiency score above 0.80. In contrast, approximately 40.00% of farms with scores below 0.80 indicate significant potential to improve input use. In particular, 2.10% of farms (3 farms) have a score below 0.60, indicating a serious waste of resources. Examining socioeconomic factors such as land size, farmers' education levels, age, agricultural experience, and the financial status of these low efficiency farms could be important for developing targeted intervention programs.

Economic Efficiency and Allocative Efficiency

Economic efficiency is the determination of efficiency based on cost. The most economically efficient production method is the one with the lowest cost among the alternatives. Allocative efficiency, on the other hand, is an indicator of how producers operate both technically and economically, and it is obtained by dividing the economic efficiency value by the technical efficiency value.

The study examined not only how well farms managed their production process (technical efficiency) but also how accurately they made decisions regarding market conditions and input prices (allocative and economic efficiency). The distribution of economic and allocative efficiency scores for the farms is presented in Table 5.

Table 5. Comparison of technical, economic and allocation efficiencies of enterprises

	Constant return to scale (CRS)		Variable return to scale (VRS)	
Efficiency	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**
Technical efficiencies	0.69	0.20	0.88	0.13
Economic efficiencies	0.52	0.25	0.72	0.22
Allocation efficiencies	0.75	0.27	0.82	0.21

In Table 5, the average economic efficiency of farms under the VRS assumption was calculated as 0.72. This indicates that farms can reduce total costs by an average of 28.00% while maintaining current production levels. The source of this 28.00% total cost saving is both technical and allocative inefficiency. This situation

indicates that, although the surveyed farms largely know how to produce (e.g., how to cultivate, when to irrigate), they cannot achieve comparable success in selecting the optimal input combination at the right price.

The average allocative efficiency of 0.82 suggests that producers remain insensitive to changes in input prices or experience difficulties in accessing market information. This situation indicates that farms increase their costs by an average of 18.00% simply by choosing the wrong input combination. This inefficiency stems primarily from mismanagement of input timing and quantities, such as fertilizers and pesticides, and is accompanied by price fluctuations.

Overall, higher technical efficiency and lower economic and allocative efficiencies indicate that price imbalances and weaknesses in producers' economic decision making mechanisms significantly limit efficiency performance. Even if producers are technically more efficient, they increase their costs and reduce their profitability due to misallocations of inputs.

Külekci (2010), categorized farms according to their size, determining the technical efficiency score for small farms to be 0.58 and for large farms to be 0.73. He found the average technical efficiency score for farms to be 0.65. He stated that large-scale farms are more efficient in the region and that producers could reduce their inputs by approximately 56.00 percent by improving their technical efficiency without reducing sunflower production, based on these findings, he emphasized the need to improve extension services, such as farmer training programs, to enhance technical efficiency, alongside expanding production across larger areas. Parlakay, (2016), calculated the farms' technical efficiency scores as 0.82 under the CRS assumption and 0.83 under the VRS assumption. The VRS technical efficiency score in our study is higher than that found by Parlakay (2016), suggesting that the farms examined operate with greater technical efficiency. Savaş and Işın (2024) found that the technical efficiency score for farms using advanced irrigation technology was 0.72, for those producing without irrigation it was 0.81, and the overall technical efficiency score was 0.74. The CRS technical efficiency score in our study is lower than the overall average reported by Savaş and Işın (2024). However, our VRS technical efficiency score is higher than that of both groups in Savaş and Işın (2024). This suggests that the farms in our study have higher technical potential or could be more efficient if scale inefficiencies were eliminated.

CONCLUSION

The study reveals that while confectionery sunflower producing farms in the Pasin Plain exhibit high levels of technical efficiency, their economic efficiency remains comparatively low. This finding indicates that producers are capable of effectively managing the production process from a technical standpoint, however, farms fall short in achieving sufficient efficiency in input combination selection, cost control, and price-based economic decision making processes. A significant portion of overall inefficiency stems from scale inefficiency, highlighting that small scale farms, in particular, struggle to reduce unit costs and are more vulnerable to increases in input prices. In this context, existing digital platforms should be rolled out more widely and encouraged so that producers can closely monitor input prices and manage costs in the face of fluctuations in input prices. At this point, mobile apps such as the Tarım Cebim'de app developed by the Ministry of Agriculture and Forestry can offer significant benefits to producers. In addition, small-scale farms should be offered access to low interest loans. This will have a positive impact on the competitiveness of small farms and make it easier for them to access finance. In addition, agricultural extension and consultancy services should be restructured to go beyond the mere transfer of technical knowledge to encompass cost management, market information, and financial literacy. Furthermore, supporting structural arrangements aimed at mitigating scale issues, such as cooperativization and land consolidation, and developing targeted policy instruments for low efficiency farms are crucial for enhancing the sustainability and economic performance of confectionery sunflower production in the region.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

The authors declare that they have contributed equally to the article.

ORCID

Emirhan Yılmaz KAVRAN https://orcid.org/0000-0003-4759-9893
Vedat DAĞDEMİR https://orcid.org/0000-0002-2293-9460

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