Revista Mexicana de Ciencias Agrícolas
REMEXCA

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Article

Unified analysis of the technical efficiency of sugar production in Mexico

Mario Iván García-Hernández[1]
Román Morales-Pablo[2]
Verónica Guízar-Serrano[3]
Fermín Sandoval-Romero[4,§]

1 Consultor/Investigador Independiente. Av. Úrsulo Galván 36A, Colonia Salitrería, Texcoco, Estado de México, México. CP. 56150.

2 Universidad Tecnológica de Gutiérrez Zamora-Ingeniería en Agrobiotecnología. Carretera Gutiérrez Zamora-Boca de Lima km 2.5, Gutiérrez Zamora, Veracruz, México. CP. 93556.

3 Posgrado del Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y la Agricultura Mundial-Universidad Autónoma Chapingo. Carretera México-Texcoco km 38.5, Chapingo, Texcoco, Estado de México. CP. 56230.

4 Universidad Autónoma Chapingo. Carretera México-Texcoco km 38.5, Chapingo, Texcoco, Estado de México. CP. 56230.

Autor para correspondencia: fsandoval.romero@gmail.com .

Abstract

In Mexico, sugarcane is an important crop because it is the primary input for sugar production and impacts employment generation in 15 states and 272 municipalities. This study aimed to estimate the technical efficiency of sugar mills of the 2022-2023 harvest in the production of standard sugar. The methodology used was the stochastic nonparametric envelopment of data (StoNED) analysis, which unifies the approaches of data envelopment analysis and stochastic frontier analysis. The results showed the existence of heterogeneity in the relative technical efficiency of sugar production across the mills. Five groups of mills were identified: a) ten mills with optimal efficiency; b) 25 mills with high relative efficiency; c) four mills at the threshold of high relative efficiency; d) five mills with potential for improvement; and e) a mill in a critical situation due to its high technical inefficiency (26%), which was El Carmen. The average efficiency of agribusiness was 96%. It is concluded that there is a regularity in the behavior of the El Carmen and El Mante mills as two decision-making units, which, given their high inefficiency in the production of standard sugar, due to causes attributable to their management and production practices, could stop operating temporarily or permanently.

Keywords:

data envelopment analysis, esource and input management, stochastic frontier, technical inefficiency.

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Introduction

Sugarcane in Mexico is essential because it is the input of the primary sweetener used in the country, which is cane sugar, which has a 77.54% share of the Mexican sweetener market demand (Santillán *et al* ., 2017 ; CONADESUCA, 2025) and impacts employment generation in 15 states and 272 municipalities (CONADESUCA, 2024).

In the 2023-2024 harvest, 271 303 direct jobs were generated in 49 mills in the field and factory links of the sugarcane mills (CNIAA, 2024). In 2023, sugarcane generated 5.7% of the total value of cyclical and perennial crop production (SIAP, 2025).

In recent decades, multidimensional efficiency analysis methodologies, in which multiple inputs and multiple outputs are considered simultaneously, have been gaining prominence (Johnson and Kuosmanen, 2011). The two methodologies that have been most developed are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). DEA has been applied in a multitude of areas, including agriculture.

Aldaz and Millán (2003) compared the nonparametric methodologies of the Malmquist index and the DEA to quantify agricultural efficiency in the European Union for the 1985-2000 period and concluded that the evaluation of efficiency with slightly different approaches to the same methodology is significantly affected.

Santiago *et al* . (2021) applied the DEA analysis in their variant of the Malmquist index to a balanced sugarcane panel dataset comprising 50 sugar mills that operated during the 2006-2007-2015-2016 harvest period. Their results showed that the San Miguel del Naranjo mill had falls of -10.4% in productivity, with setbacks in technical efficiency (-10.2%) and technology (-0.3%), and that, for the study period, 20 mills had negative productivity, and in 30 mills, this indicator improved.

Valdivia *et al* . (2022) analyzed the efficiency and nature of returns to scale for sugar mills that milled in the 2010-2011 harvest. The results showed that 23 mills operated at their optimal scale, nine mills at total efficiency, but with pure inefficiency and scale inefficiency, and a third group operated with total inefficiency, pure inefficiency, and scale inefficiency, and that 23 mills operated with constant returns to scale, 29 with increasing returns to scale, and only two mills with decreasing returns to scale. The main conclusion indicates that the 29 mills with increasing returns to scale could improve their performance if they expanded their size, since production and factor productivity would increase more than proportionally.

The stochastic frontier methodology has been applied very limitedly in Mexico and in agriculture, except for Ortega *et al* . (2025) ; Sandoval *et al* . (2025) . Authors such as Ortega *et al* . (2023) analyzed the technical efficiency of sugarcane in Mexico using the stochastic production frontier, based on data from the 2019 National Agricultural Survey (INEGI, 2020). Their main result was that, at the sugarcane production unit level, the average technical efficiency was only 47%, with a range of variation from 15% to 71%, which means an opportunity to improve technical efficiency at the production unit level.

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Stochastic production frontier analysis is one of the two methods used to estimate the inefficiency of units of analysis; the other is data envelopment analysis, which estimates the efficiency of decision-making units in a nonparametric and deterministic way. However, the rapid advancement and development of new techniques in the field of technical, allocative, and economic efficiency now allows us to estimate this efficiency indicator by unifying the two approaches in what has been called stochastic nonparametric envelopment of data (StoNED) analysis (Andor and Hesse, 2014 ; Kuosmanen *et al* ., 2015).

In this context, the objective of this research is to estimate the technical efficiency of the mills in the production of the standard sugar of the sugarcane agribusiness in order to determine which were the decision-making units with the best performance in terms of technical efficiency during the milling of the 2022-2023 harvest of the sugarcane agribusiness in Mexico.

Materials and methods

In the analysis, the primary sources of information were the statistical report on sugarcane agribusiness of the National Union of Sugarcane Growers (UNC-CNPR, 2024) and the Mexican sugar manual of the CNIAA (2024) . The variables used in the research are described in Table 1 .

Table 1. Definition of the variables used in the research.

Variable	Description	Units
Stasu	Standard sugar produced	(t)
Ragrca	Raw ground cane	(t)
Bubag	Burnt bagasse	(t)
Lab	Labor	People
Iare	Industrialized cane area	(ha)
Haveh	Hauling vehicles	Number
Elcon	Electricity consumption	(kW h^{-1})

Prepared based on UNC-CNPR (2024) .

The method used to estimate the technical efficiency (or inefficiency) of decision-making units (DMU) is a nonparametric method that combines convex nonparametric least squares (CNLS) with the stochastic nonparametric envelopment of data (StoNED) (Kuosmanen *et al* ., 2015).

In the first stage, we work with the CNLS model, in which the convex production frontier is estimated by solving the optimization problem $min_{\alpha i,\beta i,\varepsilon i}\sum_{i=1}^{n}\epsilon_i^2$ subject to the constraints: 1) adjustment restrictions for each DMU_i : $y_i=\alpha_i+\beta_i^{'}x_i-\epsilon_i$ 2). Convexity constraints for all pairs of units (i, j) that guarantee that the production frontier is convex: $\alpha_i+\beta_i^{'}x_j\leq\alpha_i+\beta_j^{'}x_j$ 3). Monotonicity constraints that guarantee that the increase in any input does not result in a reduction in output since the coefficients are non-negative: $\beta_i\geq 0$, where n= is the total number of decision-making units or units of analysis; α_i = is the intercept for the DMU_i ; β_i = is the vector of coefficients or slopes that is the marginal contribution of each output in the DMU_i ; ε_i = is the compound error term (statistical noise and

DOI: https://doi.org/10.29312/remexca.v17i1.3958

technical inefficiency) for the DMU_i ; y_i = is the output observed of the DMU_i ; x_i = is the vector of inputs of the DMU_i ; $\beta_i^{'}x_i$ = is the scalar product of the coefficients and inputs (linear impact of the inputs on the output).

Once the CNLS residues have been estimated in the first stage, they are used in the second phase, in which they are decomposed into $\varepsilon_i = v_i - u_i$. Where: $v_i \sim N(0, \sigma_v^2)$, and the error that represents the technical inefficiency u_i ; in this paper, it is assumed that it is distributed asymmetrically by means of a half-normal distribution and $u_i \geq 0$. Estimation of the parameters requires estimating the variance of statistical noise (σ_v^2) and the variance of inefficiency (σ_u^2) by maximum likelihood (MLE), maximizing: $L(\sigma_v^2,) = \sum_{i=1}^{n} f(\varepsilon_i|\sigma_v^2, \sigma_u^2)$, where $f(\bullet)$ = is the joint density function of $v_i - u_i$. The expected value of the error representing the inefficiency u_i , conditional of statistical noise ε_i , is estimated using the so-called predictor of Jondrow *et al* . (1982) , which is: $E(u_i|\varepsilon_o) = \sigma\left[\frac{\lambda}{1-\lambda^2}\right]\left[\frac{\varphi(z_i)}{1-\Phi(z_0)} - z_i\right]$. Where: $\varphi(\bullet)$ and $\Phi(\bullet)$ correspond to the density function and the cumulative distribution of a standard normal distribution, respectively and the expression $\lambda = \frac{\sigma_u}{\sigma_v}$ represents the ratio of inefficiency over statistical noise; $\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$ is the joint standard deviation, and $z_i = \frac{\varepsilon_i\lambda}{\sigma}$ is a standardized auxiliary variable.

To make the CNLS-StoNED model operational, the multiplicative form of the compound error was assumed, which results in the expression for the calculation of u_i being now $\varepsilon_i = \ln y_i - \ln f(x_i)$. This also makes it easier to interpret u_i because technical inefficiency will now be a percentage of the output. An advantage of the CNLS-StoNED approach is that it allows us to discriminate causes that are merely random and beyond the control of the respective decision-making unit or the particular administrator. The estimation of the empirical model was carried out using the Benchmarking package of the R 4.2.3 program, developed by Bogetoft and Otto (2025) . Finally, it is necessary to note that the definition of the ranges of values of the efficiency scores in which the sugar mills were grouped was based on Cooper *et al* . (1984).

Results and discussion

The relevant descriptive statistics of the variables of the estimated model, which correspond to cross-sectional data from 47 sugar mills out of the 49 that operated in the 2022-2023 harvest, are presented in Table 2 .

Table 2. Descriptive statistics of the variables of the model used.

Variable	Media	Standard deviation	Valor	
			Minimum	Maximum
Stasu	126 301	69 126.7	12 232	289 823
Ragrca	1 114 499	603 772.1	129 485	2 753 533
Bubag	303 925	170 016.6	880	797 902
Lab	5 151	2 813.6	732	16 291
Iare	16 218	9 980	6	47 300

Revista Mexicana de Ciencias Agrícolas REMEXCA

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Variable	Media	Standard deviation	Valor	
			Minimum	Maximum
Haveh	339	313.2	48	1 947
Elcon	26 069 204	32 536 679	1 744 580	222 472 745

The variables and their physical units are those given in the first table. Prepared based on UNC-CNPR (2024) .

Based on the estimated model results, it is possible to distinguish five groups of mills according to their technical efficiency, estimated using the CNLS-StoNED approach. In the first, there are 10 sugar mills with optimal technical efficiency (100%) located along the observed efficiency frontier. These mills are Alianza Popular, Atencingo, Central Casasano, Central Progreso, El Molino, Emiliano Zapata, Plan de San Luis Potosí, La Fe Pujiltic, Quesería and Tamazula.

In a second group, there are 25 sugar mills, which were called mills of high relative technical efficiency or quasi-efficient mills, whose efficiency score range extends from 90.4% to 97.97%. At the lower limit of this group is the Motzorongo mill with an efficiency of 90.4% and an inefficiency of 9.6% attributable exclusively to causes of management of resources, inputs, and practices under the control of said DMU and not to merely random causes that are beyond the control of the mill, such as excessive rainfall or droughts, among others.

This is the key difference of the method used in this research, the stochastic nonparametric envelopment of data (StoNED) analysis and the data envelopment analysis (DEA), where all the technical inefficiency is attributed exclusively to the management of the production unit in question, since this method does not include a statistical error that reflects the inefficiency attributable only to random factors beyond the control of the managers of the respective mill. At the upper limit is the Plan de Ayala mill with a technical inefficiency of 2.1%, so it is at the threshold of efficient mills with optimal performance. This group of mills is shown in Table 3 .

Table 3. Mills with high relative technical efficiency or quasi-efficient mills.

Mill	Efficiency (%)	Mill	Efficiency (%)
Motzorongo	90.4	Bellavista	95
La Gloria	90.9	Tala	95
San Rafael	90.9	Santa Clara	95.2
Eldorado	91.7	Pedernales	95.6
La Providencia	92.3	El Higo	95.8
Mahuixtlán	92.5	El Refugio	96
San Cristóbal	92.6	Lázaro Cárdenas	96.3
Tres Valles	92.7	San Miguel El Naranjo	96.8
Presidente Benito Juárez	92.8	Puga	96.9
El Potrero	93.8	La Margarita	97.2
San José de Abajo	93.2	Melchor Ocampo	97.8

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Mill	Efficiency (%)	Mill	Efficiency (%)
Zapoatipa	93.3	Plan de Ayala	97.9
Cuatotolapam	94		

Prepared based on UNC-CNPR (2024) .

In a third group, it was possible to place four sugar mills that can be characterized as mills whose efficiency score ranged between 89.2% and 89.7%; that is, they are mills that are on the threshold of being considered high-efficiency or quasi-efficient mills. This group is shown in Table 4 .

Table 4. Mills on the threshold of high technical efficiency.

Mill	Efficiency (%)	Mill	Efficiency (%)
El Mante	89.2	Constancia	89.3
El Modelo	89.2	Adolfo López Mateos	89.7

Prepared based on the Benchmarking package (2025).

In a fourth group, there are five mills, which, following Cooper *et al* . (1984), have been called mills with potential for improvement in their technical efficiency. However, their situation already reflects a certain degree of critical status, so it is advisable to improve production practices and the management of resources and inputs over which these economic units have control. As mentioned, their technical inefficiency is attributed to the productive practices, management, administration, and social relations between sugarcane suppliers and sugar industrialists, which are not purely random events, such as climatic factors and others that are totally beyond the control of these decision-making units. This group of sugar mills consists of those presented in Table 5 .

Table 5. Mills with the potential to improve technical efficiency.

Mill	Efficiency (%)	Mill	Efficiency (%)
Calipam	82.2	San Miguelito	84.4
San Pedro	83.1	San Nicolás	84.8
Santa Rosalía	84.1		

Prepared based on the package R-Benchmarking (2025).

In a fifth group, although with only one mill, is the El Carmen sugar mill, whose performance, in terms of technical efficiency, places it in a critical situation. Its technical inefficiency reached 26% in the study harvest, as determined with the methodology used, and as mentioned, technical inefficiency is attributable to causes within the decision-making unit itself.

Finally, the average relative technical efficiency of the 47 mills considered in the research was 94%. This number can be considered as an average for sugarcane agribusiness in Mexico, so it can be asserted that the national agribusiness is a sector with high relative technical efficiency. Nevertheless, the 6% inefficiency is due to causes not attributable to merely random phenomena, such as climate, but to the management capacity and productive practices of the resources and inputs of the decision-making units of said agribusiness.

DOI: https://doi.org/10.29312/remexca.v17i1.3958

To discuss the results of this research, no similar study was found, to the best of our knowledge, that used the CNLS-StoNED methodology in agriculture or sugarcane at the sugar mill level. Some studies have applied either data envelopment analysis or the stochastic frontier separately. Sandoval *et al* . (2025) applied stochastic frontier analysis to evaluate the agroindustrial yield or sucrose per hectare of sugar mills and found that, of the 37 sugar mills studied, two of them were the ones with the highest technical inefficiency of agroindustrial yield: El Mante with an inefficiency of 11.4% and El Carmen with a technical inefficiency of 15.1%.

Although El Mante had a technical inefficiency of 10.8% in the present research, in the work by Sandoval *et al* . (2025) , who applied the stochastic frontier exclusively, it had a technical inefficiency of 15.1%. As observed, the StoNED methodology allowed us to estimate a lower inefficiency score attributable to the productive and management practices of said mill; in essence, its situation is worrying and could lead to it ceasing operations either temporarily or permanently. The same reasoning applies to the case of the El Carmen sugar mill.

Ortega *et al* . (2023) also applied the stochastic frontier approach to estimate the technical efficiency of the sugarcane industry using data from the 2019 National Agricultural Survey (INEGI, 2020) and found that the average score of the sugarcane industry for that indicator was 47%, varying in a range from 15% to 71%. This level of efficiency contrasts with the agribusiness average of 96% estimated by Sandoval *et al* . (2025) .

Nonetheless, it should be noted that the work of Ortega *et al* . (2023) was based on information from the 2019 National Agricultural Survey (INEGI), so the estimate of the efficiency index included more than thirteen variables and refers to decision-making units at the level of agricultural production units rather than at the level of sugar mills.

Escobedo *et al* . (2019) , using data from the 2015-2015 harvest, calculated the technical efficiency of the 50 sugar mills that operated in that harvest using the data envelopment analysis and found that the average efficiency of the agribusiness was 89% when they did not consider the mechanization of the cane harvest, and it rose to 96.5% when they considered the mechanization of the cutting and collection of cane. In this study, it was found that the four mills with the lowest technical efficiency were El Carmen, San José de Abajo, El Refugio and El Mante, whose relative technical efficiency is 69%, 69.8%, 75% and 76.4%, respectively.

As can be seen, El Carmen and El Mante have been two mills that, in the studies reviewed, using data envelopment analysis, the stochastic frontier or StoNED, which unifies both methodologies, have shown poor performance in terms of their technical efficiency.

DOI: https://doi.org/10.29312/remexca.v17i1.3958

Conclusions

The analysis was based on the use of the Stochastic Nonparametric Envelopment of Data (StoNED) approach, which represents the unification of two previously distinct approaches: data envelopment analysis and stochastic frontier analysis.

The methodological integration allows us to consider during the analysis both the nonparametric and axiomatic characteristics of the data envelopment analysis, which is helpful to handle multiple inputs and multiple outputs without assuming a specific functional form and the capacity of the stochastic frontier analysis to model the statistical noise of the production processes, which yields a robust evaluation of technical efficiency.

The findings of this research have revealed significant variation in the levels of technical efficiency across the mills that make up the Mexican sugarcane agribusiness. This made it possible to identify groups of mills ranging from those with optimal efficiency, reaching 100%, to others that show high relative efficiency, mills on the threshold of achieving this high efficiency, and finally, mills with clear potential for improvement.

In this context, the El Mante and El Carmen mills are a particularly notable case, since both have shown a tendency to exhibit persistent technical inefficiency compared to the rest of the mills analyzed, as shown by previous studies on technical efficiency as in this work.

Bibliography

1 Aldaz, N. and Millán, J. A. 2003. Análisis Malmquist y DEA intertemporal de las agriculturas de la Unión Europea. Economía Agraria y Recursos Naturales. 3(6):45-64. https://recyt.fecyt.es/index.php/ECAGRN/article/view/14440.

2 Andor, M. and Hesse, F. 2014. The StoNED age: departure into a new era of efficiency analysis? A Monte Carlo comparison of StoNED and the ‘oldies’ (SFA and DEA). Journal of Productivity Analysis. 41(1):85-109. Doi: https://doi.org/10.1007/s11123-013-0354-y.

3 Bogetoft, P. and Otto, L. 2025. *Benchmarking: benchmark and frontier analysis using DEA and SFA* (version 0.33) [package de R]. R Foundation for Statistical Computing. 48-59 pp. https://CRAN.R-project.org/package=Benchmarking.

4 CNIAA. 2024. Cámara nacional de las industrias alcoholera y azucarera. El manual azucarero mexicano. Compañía Editorial del Manual Azucarero. 177-394 pp. https://www.manualazucarero.com.

5 CONADESUCA. 2024. Comité nacional para el desarrollo sustentable de la caña de azúcar. 11 informe estadístico del sector agroindustrial de la caña de azúcar en México, zafras 2014-2015/2023-2024. 2-10 pp. https://www.siiba.conadesuca.gob.mx/siiaca/docext/11vo-Informe-Estadistico.pdfhttps://doi.org/10.1016/0304-4076(82)90004-5.

6 CONADESUCA. 2025. Comité nacional para el desarrollo sustentable de la caña de azúcar balance nacional de edulcorantes. Ciclo 2024/2025. 1-5 pp. https://www.gob.mx/cms/uploads/attachment/file/977417/2doBal-est-24-25-2.5-meses-.pdf.

7 Escobedo, C. O. A. y Valdivia, A. R. 2019. Análisis de la eficiencia técnica de la agroindustria de la caña de azúcar en México con el análisis envolvente de datos. Revista Mexicana de Economía Agrícola y de los Recursos Naturales. 12(1):72-91. http://dicea.chapingo.mx/wp-content/uploads/2019/07/ENERO-JUNIO-2019.pdf.

DOI: https://doi.org/10.29312/remexca.v17i1.3958

8 INEGI. 2020. Instituto Nacional de Estadística y Geografía. Encuesta Nacional Agropecuaria 2019. https://www.inegi.org.mx/programas/ena/2019/#Tabulados.

9 Johnson, A. L. and Kuosmanen, T. 2011. A bridge too far? The state of the art in combining the virtues of stochastic frontier analysis and data envelopment analysis. Operations Research. 59(6):1355-1371. https://doi.org/10.1287/opre.1110.0962.

10 Jondrow, J.; Lovell, C. A. K.; Materov, I. S. and Schmidt, P. 1982. On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics. 19(2-3):233-238. Doi: https://doi.org/10.1016/0304-4076(82)90004-5.

11 Kuosmanen, T. and Kortelainen, M. 2012. Stochastic non-smooth envelopment of data: semiparametric frontier estimation subject to shape constraints. Journal of Productivity Analysis. 38(1):11-28. Doi: https://doi.org/10.1007/s11123-010-0201-3.

12 Kuosmanen, T.; Johnson, A. and Saastamoinen, A. 2015. Stochastic nonparametric approach to efficiency analysis: a unified framework. *In*: Zhu, J. Ed. Data Envelopment Analysis. Springer. 191-244 pp. Doi: 10.1007/978-1-4899-7553-9-7.

13 Muyanga, M. and Jayne, T. S. 2019. Revisiting the farm size-productivity relationship base on a relatively wide range of farm sizes: evidence from Kenya. American Journal of Agricultural Economics. 101(4):1140-1163. Doi: https://doi.org/10.1093/ajae/aaz003.

14 Omotilewa, O. J.; Jayne, T. S.; Muyanga, M.; Aromolaran, A. B.; Liverpool, T. L. S. and Awokus, T. 2021. A revisit of farm size and productivity: empirical evidence from a wide range of farm sizes in Nigeria. World Development. 146:1-15. Doi: https://doi.org/10.1016/j.worlddev.2021.105592.

15 Ortega, D. A.; Flores, S. M. and Aguilar, R. A. N. 2025. Stochastic frontier analysis and agricultural typologies: applied to Mexico's sugarcane industry. Regional Science Policy & Practice. 17(4):1-18. Doi: https://doi.org/10.1016/j.rspp.2025.100173.

16 Sandoval, R. F.; Cuevas, A. C. M.; Montiel, B. B. M. y Altamirano, C. J. R. 2025. Evaluación del rendimiento agroindustrial del azúcar de los ingenios azucareros de México. Revista Mexicana de Ciencias Agrícolas. 16(5):1-10.

17 Santiago, Z. I. M.; Martínez, D. M. Á.; Cuevas, A. C. M.; Valdivia, A. R.; García, H. M. I. y Hernández, T. J. 2021. Productividad y cambio tecnológico en la agroindustria de la caña de azúcar en México. Revista Mexicana de Ciencias Agrícolas. 12(6):1005-1017. Doi: https://doi.org/10.29312/remexca.v12i6.2692.

18 Santillán, F. A.; García, L. R.; Vásquez, B. N.; Santoyo, C. V. H.; Melgar, M. M.; Pereira, W.; Larrahondo, A. J. E. y Merino, G. A. 2017. Impacto de la sustitución del azúcar de caña por edulcorantes de alta intensidad en México. Universidad Autónoma Chapingo (UACH). 125-126 pp. https://ciestaam.edu.mx/publicaciones2018/libros/edulcorantes.pdf.

19 UNC-CNPR. 2024. Unión Nacional de Cañeros, AC. Confederación nacional de propietarios rurales. Estadísticas de la agroindustria de la caña de azúcar 2013-2022. Ciudad de México, México. 21vª. Edición. 190-297 pp.

Unified analysis of the technical efficiency of sugar production in Mexico

Journal Information
Journal ID (publisher-id): remexca
Title: Revista Mexicana de Ciencias Agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
ISSN (electronic): 2007-9934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 01 September 2025
Date accepted: 01 January 2026
Publication date: 01 January 2026
Publication date: Jan-Feb 2026
Volume: 17
Issue: 1
Electronic Location Identifier: e3958
DOI: 10.29312/remexca.v17i1.3958
Publisher ID: 00007

Categories

Subject: Article

Keywords:

Keywords:

data envelopment analysis

resource and input management

stochastic frontier

technical inefficiency

Counts

Figures: 0

Tables: 5

Equations: 0

References: 19