Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v16i4.3701

Article

Current economic analysis of corn in Mexico, period 1981-2022

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Abstract

The research used an econometric model consisting of a system of simultaneous equations for the period from 1981 to 2022. This work aimed to develop an econometric model to determine the current conditions of commercialization and estimate the effect of the different prices that incur on producer and consumer prices, on demand, supply, and the foreign trade balance of the corn market in Mexico. The hypothesis tested was that the functioning of the corn market is determined by the current commercialization situation, the behavior of supply and demand and it is influenced by production and the related and international prices of this grain. In the results, the correct signs were obtained in the estimated functions of supply and demand, which had significantly expected positive effects on the quantity of corn produced and the normal behavior of the prices that incur in demand, reflected in direct relationships with respect to those related and adverse relationships regarding income variables and crops that compete for the same resources.

Palabras clave:

economía, maíz, sector agroalimentario.

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Introduction

In the last ten years (2012-2022), the average production of corn was 1 120.8 million tons, with an average annual growth rate (AAGR) of 5.1%, making it the most produced cereal worldwide. Of the world production, 62.4% is concentrated in three countries: the United States of America (USA) participated with 31.8%, followed by China 22.8%, and Brazil 7.9%. Mexico's share is 2.4%, with a AAGR rate of 1.9% (FAO, 2024; López *et al*., 2021). In Mexico, corn is a staple food in the diet as it accounts for a quarter of the caloric intake (OECD-FAO, 2022).

The average production of corn was 23.1 million tons, of which four entities contribute 48.9%, with Sinaloa (20.1%) being in the northwest region, Jalisco (12.2%) and Michoacán (8%) in the central-west region, and the state of Mexico (8.5%) in the central zone, whereas more than 50% is distributed throughout the national territory. Baja California Norte and the Distrito Federal occupy the last two places of production. The most stable AAGR is recorded by Sinaloa, at 3.9%, whereas the lowest is recorded by Chiapas. In 2022, Mexico produced 26.6 million tons, exported 0.1% of its production, and imported 16.3% (SIAP-SADER, 2024; SIACON, 2024).

Corn imports have exceeded the quota established in the North American Free Trade Agreement (NAFTA), and it was not until 2000 that the government implemented the general import tax. For corn imported from the US, the European Community, Colombia, Venezuela, Costa Rica, Bolivia, Chile, Nicaragua, and Israel, a tariff of 1% and 3% was established for yellow and white corn, respectively (Lezama *et al*., 2018). There have been reforms in the strategies in trade liberalization through institutions (Maximiliano, 2011; SAGARPA, 2017; Téllez *et al*., 2023) to control imports of staple grains since these complement the deficit (Valencia *et al*., 2019).

Measures to address the food and socioeconomic development problems faced by people in highly marginalized areas are one of the most important aspects and should therefore be prioritized in national socioeconomic plans (Sánchez, 2014; Amaro and de Gortari, 2016; Mariscal *et al*., 2017; López and Sandoval, 2018; GM, 2019; Giordano and Ortiz, 2020).

The creation of different forms of organization in the agrifood sector makes it necessary to know the panorama of such conditions (Rivera, 2021; Fletes *et al*., 2021; Morales *et al*., 2023), using econometric models by considering equations of (Araujo, 2011): supply (determined by the price for the producer, competitive or associated goods, inputs, technology, taxes or subsidies, climate, producer expectations and number of competitors), demand (explained by the price to the consumer, the price of substitute or complementary goods, population, income, consumer expectations [quantity and expected price], tastes, and preferences), levels of transmission of real prices and identity (foreign trade balance) (Reyes *et al*., 2022; Barkley and Barkley, 2024).

The research aimed to develop an econometric model to determine the current conditions of commercialization and estimate the effect of the different prices that incur on producer and consumer prices, on demand, supply, and the foreign trade balance of the corn market in Mexico. The proposed hypothesis was: the functioning of the corn market in Mexico is determined by the current commercialization situation, the behavior of supply and demand, and it is influenced by production and by related and international prices of this grain.

Materials and methods

The formulation of the model was supported on theory based on Wooldridge (2010); Gujarati and Porter (2010), to use a system of simultaneous equations based on the small country hypothesis, which states that national policies do not affect the international price, thus, national organizations and consumers must consider the international price when making production decisions.

In the specification of the model, the total supply will be equal to the total demand for corn, which will be made up of the national production of corn plus imports, whereas the demand for corn will be given by the sum of the different demands for the use of corn according to (SIAP-SAGARPA, 2017) (human, livestock, industrial-starch, seed for sowing, and losses), being specified in equation

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($QPC_t + M_t$)= ($DC_t + X_t$) 1). Where: QPC_t= production of corn in year t. DC_t= demand for corn in year t. M_t= corn imports in year t. X_t= corn exports in year t.

In this way, the trade balance (TB) will be determined by the difference between imports (*Mt*) and exports (X_t); likewise, by the difference between the demand for corn (DC_t) and the quantity produced (QPC_t), as mentioned below: $TB_t = (M_t - X_t)$ 2); $TB_t = (DC_t - QPC_t)$ 3). According to economic theory, if $TB_t > 0$, the country is in the situation of an importing country.

It is important to note that from equation 1, it is obtained that imports are given by: $M_t = [(DC_t - QPC_t) + X_t]$ 4). From which it can be discerned that the domestic demand for corn or the apparent national consumption of corn will be given by: $DC_t = QPC_t + (M_t - X_t)$ 5). Considering the above equations, demand is defined according to various factors, such as the following demand: $DCt = f(RCCP_{t-2}, RSCP_{t-2}, RGNI_{t-2}, POP_t, RER_{t-1}, D, \varepsilon)$. 6). Where: DC_t= demand for corn in year t; $RCCP_{t-2}$= real consumer price of corn in year t-2; $RSCP_{t-2}$= real consumer price of sorghum in year t-2; $RGNI_{t-2}$= real gross net income in year t-2; POP_t= population in year t; RER_{t-1}= real exchange rate in year t-1; *D*= dichotomous variable; *D*=1 for the NAFTA period (1994-2022); *D*= 0 before NAFTA for the period (1981-1993); ε = error term.

Variables such as real gross national income (RGNI) and population (POP) in any product and service are important in demand since proportional increases are significant, presenting positive effects for the benefit of any economy or negative effects, which are counterproductive in basic or food products such as staple grains.

According to the economic theory of agricultural commercialization, the supply of a product is determined by various factors, such as price of the product, prices of the inputs used, the price of the products that compete for the use of resources, the price of the associated products, the number of hectares allocated, the intervention of the government, as well as the expectations of the producer, among others (García *et al*., 2003).

Considering the above, the supply function is defined as follows: supply: $QPC_t = (RINTP_t, RASRP_t, RUREAP_t, RGOVPR_t, RGMW_t, RABRP_t, RTORP_t, D, \varepsilon)$ 7). Where: $RINTP_t$= real international price of corn in year t; $RASRP_t$= real average rural price of sorghum in year t; $RUREAP_t$= real price of urea in year t; $RGOVPR_t$= real government program in year t; $RGMW_t$= real general minimum wage in year t; $RABRP_t$= real average rural price of beans in year t; $RTORP_t$= real price of tortillas in year t; *D*= dichotomous variable; *D*= 1 for the NAFTA period (1994-2022); *D*= 0 before NAFTA for the period (1981-1993). ε = error term; identity: TBt=(DCt−QPCt).

The closing condition of the model is the foreign trade balance (FTB_t) equation, which establishes the equilibrium scenario in the market by equalizing the national supply plus the foreign trade balance with the quantity demanded of corn at the national level. The foreign trade balance can be expressed as an identity equation, which means that it does not have stochastic disturbances (Cruz *et al*., 2016; Rivera *et al*., 2023).

Endogenous variables: DC_t. QPC_t. $RACRP_t$. $RTORP_t$. $RCCP_t$. FTB_t. Exogenous variables: $RSCP_t$. $RGNI_t$. POP_t. $RASRP_t$. $RINTP_t$. $RUREAP_t$. $RGOVPR_t$. $RGMW_t$. $RABRP_t$. RER_t. *D.*

This model is only a superficial representation of the corn market. According to economic theory, the supply of a product is mainly subject to the producer's profit expectations, in this way, profit depends on the volume sold, the price of the product and the average costs of production (Stamer, 1969; Cruz *et al*., 2016).

Results

The results obtained helped to corroborate the hypothesis and objectives set out in this research by analyzing the statistical results, verifying the significance of the coefficients of each equation according to economic theory (Table 1) shows the estimate of the model developed in the statistical programming language of Statistical Analysis System (SAS) version 9.3.

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Table 1. Statistical results, coefficients, and estimated elasticities, 1981-2022.

Endogenous variables	Intercept	Exogenous variables							R^2	Prob>F
		$RINTP_t$	$RASRP_t$	$RUREAP_t$	$RGOVPR_t$	$RGMW_t$	$RABRP_t$	$RTORP_t$	D_t	0.861	<0.0001
QPC_t	12 569497	1 063.56	-2 596.67	634.097	142.106	6 094.016	-44.888	734.03	1974682		
Standard error	32 05372	525.469	1 113.04	460.555	284.873	2 3428.56	147.9 58	223.23	2641310		
t ratio	3.92	2.02	-2.33	1.38	0.5	0.26	-0.3	3.29	0.75		
Elasticity		0.1868	-0.411	0.115	0.035	0.032	-0.028	0.303			
		$RCCP_{t-2}$	$RSCP_{t-2}$	$RGNI_{t-2}$	POP	RER_{t-1}	D_t			0.924	<0.0001
DC_t	-15 200 000	-153.405	-207.476	0.001	403.958	-23840.7	8 91844.9				
Standard error	6604691	382.209	390.048	0.0003	47.462	254277.3	1473021				
t ratio	-2.3	-0.4	-0.53	3.02	8.51	-0.09	0.61				
Elasticity		-0.0347	-0.0354	0.0201	1.7005	-0.0142					

With data from the Statistical Analysis System (SAS).

In the estimated supply equation (QPC), the results present a high goodness of fit, with a coefficient of determination (R^2) of 0.86, whereas in the estimated equation of demand (DC), an R^2 of 0.92 was obtained, where that estimator (R^2), according to Gujarati and Porter (2010), is a measure that indicates the fit of the regression line to the data, fluctuating between 0 and 1, where values close to 0 indicate that the line does not fit the behavior of the values of the sample data and the opposite happens when the values are close to 1, indicating a perfect fit.

Thus, in the supply equation (QPC), the percentage of variation of the dependent variable is explained by the exogenous variables by 86% and in the demand equation by 92%, showing an almost perfect coefficient of determination. According to Pérez *et al*. (2016), regarding the statistical F-test, it allows us to know the significance of the set of explanatory variables on the dependent variable, proposing a null hypothesis (Ho): all the estimated parameters, excluding the ordinate to the origin, in a regression equation are equal to zero.

Whereas the alternative hypothesis (Ha) is: at least one coefficient of this equation is different from zero; thus, in this econometric model of corn, the *p*-value when obtaining F approaches zero, implying that Ho is rejected (in general, the explanatory variables considered were significant in the explanation of the variation of the dependent variables [<0.0001] according to the F-statistic).

The asymptotic t-statistic tests the significance of each of the parameters; that is, it verifies whether the independent variable (X), corresponding to the parameter #, influences the dependent variable; here, for a parameter to be accepted, it needs the t-ratio to be equal to or greater than one to imply that the estimated coefficient is greater than its standard error (García, 2002; Pérez *et al*., 2016); likewise, values obtained in Pr>|t| approaching <0.0001 present the best estimators, as can be seen in Table 1, except for variables below this parameter, such is the case in the supply equation (QPC) for the following variables: real government program (RGOVPR), real general minimum wage (RGMW), average bean rural price (RABRP) and dichotomous variable (D).

Regarding the demand equation (DC), the situation is the same for the following variables: real consumer price of corn (RCCP), real consumer price of sorghum (RSCP), real exchange rate (RER) and dichotomous variable (D). Nevertheless, although they are not statistically significant, they are significant according to economic theory, showing themselves in the estimation results, therefore, they validate this model; Stamer (1969); Pérez *et al*. (2016) state that when the introduction of some variables is logically convincing, low statistical certainty can be tolerated, rather than accepting

DOI: https://doi.org/10.29312/remexca.v16i4.3701

others that theoretically imply doubt. The estimated coefficients were used to obtain the following functions of the corn market in Mexico.

Supply: QPC_t=12569497 + 1063.56$RINTP_t$ -2596.67$RASRP_t$ + 634.0969$UREAP_t$ + 142.1056$RGOVPR_t$ + 6094.016$RGMW_t$ - 44.8876$RABRP_t$ + 734.03$RTORP_t$ +1974682D_t.

Demand: DC_t=-15200000 - 153.405$RCCP_{t-2}$ - 207.476$RSCP_{t-2}$ + 0.000975$RGNI_{t-2}$ + 403.9576POP_t - 23840.7RER_{t-1} + 891844.9D_t.

Classical authors such as Matus (1983) and current authors such as García and Ramírez (2015) mention how the producer will produce considering the expected price of the product, this being decisive in continuing to produce, harvest, or abandon said activity in case of not recovering the average cost of production; likewise, another important factor is the price of the products with which it competes for the use of the same resources (there may be variation).

A clear illustration of this panorama is how at the national level in Mexico, vegetables compete with grains for resources, causing the price of vegetables to determine the area planted with grains; therefore, the same situation regarding the price of grains explains the behavior of the area of vegetables. Other factors, such as input prices, climatic conditions, labor, fertilizers, and rainfall, affect the planted area, whereas the payment of RGOVPR is a factor that tries to explain the behavior of the area destined for the activity.

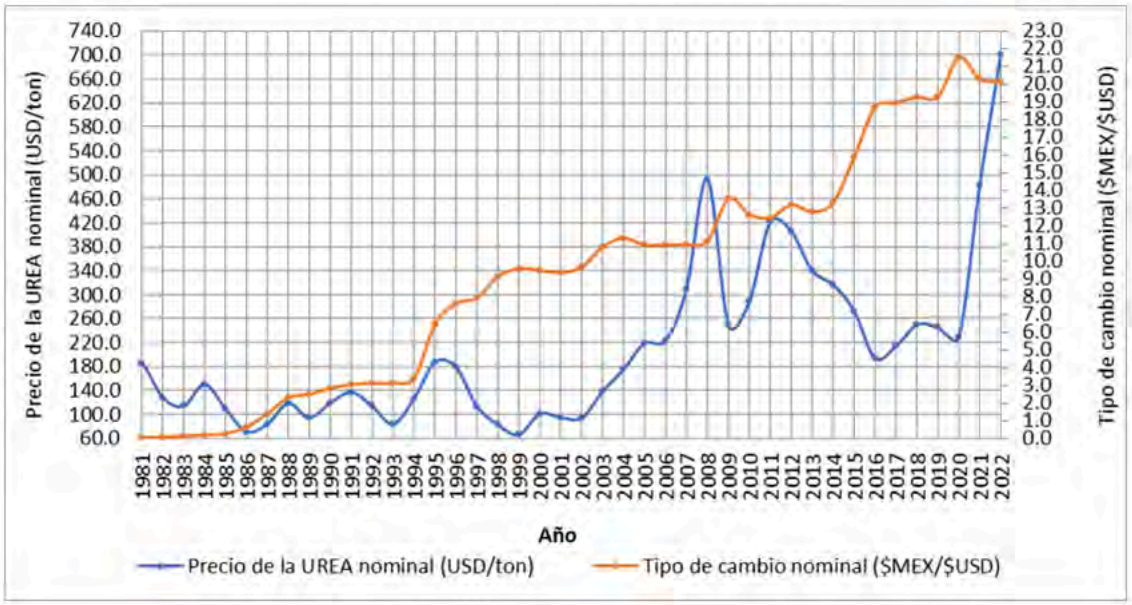
In this model, it can be seen how the international price of corn (RINTP) reacts directly because it is expected that, at a better price of corn, the quantity produced will increase, which is decisive for producers to improve their economic situation or, in an adverse context, to engage in another activity. In the same way, the estimates of the elasticities were obtained, which are interpreted as the percentage change in the dependent variable in the face of a percentage change in an independent variable, with the other independent variables *ceteris paribus*.

In the case of the elasticity that relates QPC to RINTP, it was 0.18, meaning that, if RINTP increases by 10%, then QPC will increase by 1.8%. In the case of the price of competitive goods, the real rural average price of sorghum (RASRP) has an inverse relationship with the quantity of corn produced (QPC) as there is a high correlation, a situation that is understandable because sorghum and corn (yellow) are substitutes in the diet of the livestock sector; likewise, it has an elasticity of -0.41, that is, a 10% increase in RASRP will cause a 4.1% decrease in QPC.

The parameters of the inputs do not have the expected significant signs as the elasticity that relates QPC with the real price of urea (RUREAP) is 0.115, indicating that a 10% increase in RUREAP will increase QPC by 1.15%; however, in a lack of depth analysis of this negative relationship, it may be due to the estimation of RUREAP since it considers the exchange rate (Mex pesos/USD dollar), seeing the upward behavior throughout the considered period of study (1981-2022), as observed in Figure 1.

Revista Mexicana de Ciencias Agrícolas
DOI: https://doi.org/10.29312/remexca.v16i4.3701

Figure 1. Nominal UREA price (USD t^{-1}) and nominal exchange rate ($MEX $USD^{-1}). With data from the Banco Mundial (2024); USDA (2024).



That is, farmers produce according to the price of urea, with this activity of the producers being compensated with the exchange rate since, when there is a high exchange rate, the price of urea is lower, this relationship implies that the price of urea can be relatively not so harmful when the farmer buys this input. The same described situation is shown by the RGMW variable, so incongruent estimates can be considered in this model.

One of the most significant elasticities is the real government program (RGOVPR), where the general objective is to increase the productivity of rural agricultural economic units (RAEUs) through economic incentives preferably focused on areas with medium and high productive potential, on priority crops and with market potential. The elasticity obtained for RGOVPR in relation to QPC was 0.035, that is, a 10% increase in the payment of RGOVPR will increase QPC by 0.35%.

The elasticity that relates the price of complementary products such as the real average rural price of beans (RABRP) with QPC turns out to be -0.028, indicating that a 10% increase in RABRP will decrease QPC by 0.28%. In another sense, the elasticity obtained for the real price of tortilla (RTORP) with respect to QPC is important, resulting in 0.3%, denoting that a 10% increase in RTORP will increase QPC by 3%, being decisive for the producer.

The estimated elasticities of the variables considered in the corn demand equation (DC) are described below: the elasticity that relates the real consumer price of corn (RCCP) to DC was -0.03, expressing that a 10% increase in RCCP will cause DC to decrease by 0.35%; in the same way, a 10% increase in RSCP causes DC to decrease by 0.35%.

Regarding the elasticity of the variable of real gross net income of the country (RGNI) in relation to DC is 0.02, indicating that a 10% increase in RGNI will cause DC to increase by 0.2%. Likewise, the relationship of the elasticity obtained between population (POP) and DC is direct, being 1.7, indicating that a 10% increase in POP causes a 17% increase in DC. In another sense, the elasticity obtained in the real exchange rate (RER) is -0.014, indicating that a 10% increase in RER causes a 0.14% decrease in DC.

To analyze the dichotomous variables considered in the supply and demand equations, which were: D= 1 for the NAFTA period (1994-2022); D= 0 before NAFTA for the period (1981-1993), the results show that the intercepts change due to the policy of trade liberalization with its main trading partners

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(the US and Canada) since the entry into force of NAFTA, where this important grain for the Mexican diet and economy in its productive activity follows a policy of support for the income of the producer.

Statistically, as the value of intercepts influences due to the trade policy (Moreno *et al*., 2016), the supply and demand equations can be estimated, as shown below.

Supply: original equation: QPC_t=12569497 + 1063.56$RINTP_t$ -2596.67$RASRP_t$ + 634.0969$RUREAP_t$ + 142.1056$RGOVPR_t$ + 6094.016$RGMW_t$ - 44.8876$RABRP_t$ + 734.03$RTORP_t$ + 1974682D_t.

Equation considering the dichotomous variable, D= 1 for the NAFTA period (1994- 2022), D= 0 before NAFTA for the period (1981-1993): QPC_t=14544179 + 1063.56$RINTP_t$ -2596.67$RASRP_t$ + 634.0969$RUREAP_t$ + 142.1056$RGOVPR_t$ + 6094.016$RGMW_t$ - 44.8876$RABRP_t$ + 734.03$RTORP_t$ + 1974682D_t.

In this case, the QPC curve presents a bigger intercept (14.5 million tons) compared to the intercept calculated without considering the dichotomous variable (12.5 million tons). The changes in the position of the curve in the face of changes in trade policy can be seen in an upward shift with Mexico's entry into NAFTA.

Demand: DC_t=-15200000-153.405$RCCP_{t-2}$ - 207.476$RSCP_{t-2}$ + 0.000975$RGNI_{t-2}$ + 403.9576POP_t - 23840.7RER_{t-1} + 891844.9D_t.

Equation considering the dichotomous variable, D= 1 for the NAFTA period (1994-2022), D= 0 before NAFTA for the period (1981-1993): DC_t=-14308155-153.405$RCCP_{t-2}$ - 207.476$RSCP_{t-2}$ + 0.000975$RGNI_{t-2}$ + 403.9576POP_t - 23840.7RER_{t-1} + 891844.9D_t.

In this case, the DC curve presents a lower intercept compared to the intercept calculated without considering the dichotomous variable. It is important to bear in mind that the change in magnitude in the intercepts of the supply and demand equations is due to the changes that Mexico has experienced in the agricultural policy of economic liberalization in NAFTA.

Discussion

The elasticity obtained for government support programs, RGOVPR, in relation to QPC was 0.034, that is, a 10% increase in the payment of RGOVPR will increase QPC by 0.3%. This elasticity is significant in relation to the sign to the one calculated by García and Ramírez (2015), where they obtained a value of 0.14 for the group of staple crops (grains) with respect to planted area.

The elasticity that relates the price of complementary products such as the real average rural price of beans (RABRP) with QPC was -0.028, indicating that a 10% increase in RABRP will decrease QPC by 0.28%. In another sense, the elasticity obtained for the real price of tortilla (RTORP) in relation to QPC is important, resulting in 0.3%, denoting that a 10% increase in RTORP will increase QPC by 3%, being decisive for the producer; nevertheless, in the case of consumers, their relationship is expected to be inverse, as demonstrated by Retes *et al*. (2014), where the elasticity for tortilla demand in Mexico in general is -0.38, that is, if the price rose 10% *ceteris paribus*, the quantity demanded would decrease by 3.8%; disaggregating the population by income strata, the elasticity is: low income (-0.36), medium income (-0.53), and high income (-0.66).

Conclusions

In QPC, the elasticity obtained for RGOVPR was positive, where government support will motivate farmers to produce. In the case of complementary products, such as RABRP, the elasticity was negative, indicating that its increases discourage QPC. In RTORP, the elasticity with respect to the producer is positive as it encourages its production; however, in an in-depth analysis, it is expected that the effect will be the opposite in the case of consumers.

In the case of DC, the elasticity of RCCP is negative, leading to a decrease in DC; likewise, RSCP causes DC to decrease by discouraging the cultivation of corn, whereas in variables such as RGNI and POP, the elasticity is positive, with direct exponential effects on DC. On the other hand, RER

DOI: https://doi.org/10.29312/remexca.v16i4.3701

causes a negative elasticity, leading to a decrease in DC, sending signals to the production and value chain as it is a product influenced by trade liberalization policies.

The intercepts of supply and demand change statistically, being decisive in the equations of supply and demand when considering this trade liberalization. The intercepts are statistically differential, meaning that economic policy is important in determining the production and prices of this basic grain, translating into differential effects in the determination of the endogenous variables of the analysis.

Acknowledgements

The first author thanks the National Council of Humanities, Sciences and Technologies (CONAHCYT) for the support of the postdoctoral stay at the Tejupilco Professional Academic Unit - Autonomous University of the State of Mexico (UAEMex).

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Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v16i4.3701

Current economic analysis of corn in Mexico, period 1981-2022

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

Article/Issue Information
Date received: 01 January 2025
Date accepted: 01 March 2025
Publication date: 19 June 2025
Publication date: May-Jun 2025
Volume: 16
Issue: 4
Electronic Location Identifier: e3701
DOI: 10.29312/remexca.v16i4.3701

Categories

Subject: Articles

Keywords:

Keywords:

agrifood sector

corn

economy

Counts

Figures: 1

Tables: 1

Equations: 0

References: 36

Pages: 0