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ORIGINAL ARTICLE

White Maize (Zea mays l.) Production Potential in Mexico

Potencial de producción para Maíz Blanco (Zea mays l.) en México

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Abstract
In Mexico, maize or corn (Zea mays) is the main food for ancient tradition and tortilla is the staple food base. There are many types of this grain, the most used in Mexico territory is white corn. In this paper the objectives were to get the level of corn production potential, compare it with the national demand and to determine if Mexico can be self-sufficient in corn production. A mix approach in two stages was used. The first stage consisted of searching for statistical data from official web sites. The second stage consisted on data processing. A logarithmic regression was designed to estimate the production potential and the elasticities of the production components. Results showed, at maximum potential, Mexico is capable of producing the corn that its population demands and have enough to export. Accordingly, it can be suggested to reorganize production of corn and other cereals, with special attention to the most productive zones.

Keywords: white maize, potential production , and national demand of white corn

Abstract
En México, el maíz (Zea mays) es el alimento principal por tradición milenaria; la tortilla es la base de la alimentación mexicana. Existen muchos tipos de este cereal, el más usado en el territorio nacional es el blanco. En la presente investigación, el objetivo fue obtener el nivel del potencial productivo de este grano y compararlo con la demanda nacional y determinar si el país puede aspirar a ser autosuficiente. Se utilizó un método mixto en dos etapas, una primera etapa para buscar información documental en la web y una segunda etapa en la realización de los cálculos necesarios. Se diseñó una regresión logarítmica, para estimar el potencial productivo y las elasticidades de los componentes de la producción. Los resultados mostraron que en el territorio mexicano se puede producir lo necesario que demanda la población y todavía le queda remanente para exportar, si produce a su máximo potencial. Pero, el crecimiento de la producción no fue vía rendimiento con lo que se rechazó la hipótesis propuesta. Se sugiere realizar un reordenamiento de la oferta del cereal, que las zonas productoras provean a las zonas no productoras.

Palabra clave: Maíz blanco, Potencial de producción, y Demanda nacional de maíz blanco.

1. Introduction

The maize as ancient food is distinguished by the color of its grain, its texture, its appearance and its nutritive composition, what makes it the basic product in Mexico, the place of origin. There are different types of corn, the main are: hard corn, sweet corn cultivated in small quantity, because it is not resistant to pests and diseases; The toothed maize is used for grain and silage. the floury maize is used for human consumption; the Cherry maize is used to make typical food; The corn most primitive from Mexico was the tunic maize (Zea mays tunicata). Accordingly, to its derivates, the corn races can be divided into four main races: old indigenous, pre-Columbian exotics, prehistoric mestizo and modern incipient (Wellhausen et. al, 1951).

The term maize is derivate from mahiz, ancient Word taina (extinct language nowadays) from the indigenous towns of Pre-Columbian America. Likewise, some archaeological proofs show that in ancient civilizations, maya, azteca and olmeca was the basic food and its cultivation was venerated (Centro Internacional de Mejoramiento de Maíz y Trigo, 2016).

The white maize even though has its origin center in Mexico, since the sign of the North American Free Trade Agreement has duplicated the domestic consumption, and it have had the need to realize imports of the grain from its business partners in the trade agreement: Mexico, USA and Canada (T-MEC), to complete the national demand (Luquez, et. al., 2023). However, there are other alternatives to grow the maize national production. Here is proposed to produce at its maximum potential.

The maize main producers in the world for the 2023rd are: USA, China, Brazil, and Argentina, that can provide the 76% of the global exports (Servicio de Información Agropecuaria y Pesquera (SIAP), 2023). However, the last register of the main global corn exports is on the year 2021st, indicates that USA has the first place with 70,041,368.41 tons; the second place is for Argentina with 36,911,996.44 tons; in the third place is Ukraine with 24,539,480.1 tons; in fourth place, Brazil with 20,429,565.51 tons; and in fifth place, Romania with 6,904,387.79 tons (Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), 2023).

Likewise, the main corn importers for 2021st year, in importance order were: Continental China with 28,348,177.36 tons; Mexico with 17,396,066.36 tons; Japan with 15,239,701.43 tons; Korea Republic with 11, 653, 547.68 tons; finally, in fifth place, Vietnam with 10,603,518.18 tons (Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), 2023).

Mexico has fourteen trade agreements with 50 countries. The most important is the T-MEC (United States-Mexico-Canada Agreement), to facilitate the trading among the three countries. This agreement has generated surplus for Mexico (Luquez et. al., 2022). However, the external trade also can generate negative effects over the country food sovereignty, because not all the population has the acquisitive power to buy the food that need, as the case of the maize, the big producers can prefer to export the grains instead to guaranteed the feeding inside the Mexican territory (Luquez et. al., 2023).

The maize, in Mexico is the product that generates more economic value, but also, social and cultural value. In Mexico the corn production is divided on two periods: the 25 % of the crops are produced from April to July and the 60 % from November to January (Gobierno de México, 2023).

The closing for December 2022nd, respecting to Mexico maize production in grain was 26,553,239.30 tons. Sinaloa state has the first place in production with the 20 %; in second place, Jalisco state with the 15 %; in third place Guanajuato with 7.1 %; in fourth place Mexico State with 6.7 % and in the fifth place Chihuahua with 6.5% (Servicio de Información Agropecuaria y Pesquera (SIAP), 2023).

For the year 2024th, the Mexican government implemented a guarantee Price for producers of basic grains (rice, beans, maize and wheat) also, milk. Guarantee prices and/or incentives to the production given in direct manner without intermediaries to the beneficiary. The average rural price for the year 2024th in the Mexican territory is of $6,915 pesos by ton in the production zone, this price is influenced by the changes in the international price. The program is national and is focused in the eligible producers and states where the grains and milk are produced. In the case of maize is for the small producers that have from 5 to 30 hectares (Gobierno de México, 2024).

Furthermore, this politics not always are in benefit of the small producers, for example: in the Yucatan Peninsula, some maize producers mostly ¨ejidatarios¨ are leaving without planting the grain, because of the gotten rentability is low, that is why there is a production decline. On the contrary, the producers are renting out their lands to produce in them soy, a crop more profitable, they cannot afford the cost because the soy requires high level of technification. In this sense, the land market has grown and the control has gone to the tenant producers that are not the legal owners of the land (Echánove, 2021).

The bad manage in the public politics respecting to maize in Mexico is not new; before Venegas (2016), mentioned that the producers had to protect of the financial risk, considering the derivate of the maize; that means to verify the alternatives that the producers have if there is a changing price.

By other side, in the country every year is repeated that some regions have excess of maize production, while others do not complete the intern demand, creating the need of import at any price offered from the outside; if there is production excess, the producers look for alternative markets where they get the stipulated price in order to not paying storage (Estrada et. al.2018).

According to the Organization for Co-operation and development (OCDE) and the Food and Agriculture Organization (FAO), (2023) exists an upward trend to the food international prices due to the raising in the price of the agricultural inputs after the pandemic and the raising of the fertilizer's prices, coupled with the energy price fluctuations, the seeds, the labor and the machinery, this can provoke global food shortages. Therefore, in Mexico is important to have relevant agricultural politics.

In the last administration there is a changing situation with respect to the public politics, that has affected the imports and exports of the maize grain in Mexico. The march 13th of 2020, it was published the decree of the federal law to promotion and protection of the native maize. In the article two is stated the native maize protection and its constant diversification in all the relative to the production, trade and consumption, as an state obligation to guarantee the human rights in the nutritive food, enough and high quality stablished in the third paragraph of the fourth article from the political constitution of the Mexican United States (Diario Oficial de la Federación, 2020).

Summarizing the before exposed, Mexico is the center of the maize origin and it is found inside the main importers of maize; however, there are intern problems because of the maize use cultivated surface change by other crops more profitable; adding the public politics stablished nowadays with respect to the maize and the guarantee prices for the Mexican government. In this side, is considerate relevant to investigate the white maize production in Mexico. This research has two hypotheses: 1) Mexico can satisfy the maize inside demand and 2) the maize production grows by technological change, generating high yield, and not for raising harvested area.

2. Methods and materials

The difference in the life level countries is determined by the productivity, that means, the quantity of goods and services produced by each time unit. Also, the raising rate of productivity in a country

determines the raising rate of the average income.

The production possibilities frontier shows the combinations of products that can exist in an economy, given the production factors and technology that has to become in products. This production is efficient if it is gotten the maximum benefit of the resources available; in macroeconomics is denominated gross domestic product (Mankiw, 2012). By other side, potentiality is the latent capacity or not manifest, possible or likely that have anything (Barceló, 2019).

The function of production Cobb Douglas, inside the economic theory relates the change in the production by the inputs, in the random form (Equation 1):

$$Y_i = \beta_1 X_{2i}^{\beta 2} X_{3i}^{\beta 3} e^{ui} \quad (1)$$

Where:

Y= Yield

X2= labor input

X3= capital input

u= stochastic disturbance term and

e = natural logarithm base

In this equation, the relation between the production and the inputs is not lineal, it is needed to realize a transformation through the logarithm function (Equation 2).

$$lnY_i = ln\beta_i + \beta_2 lnX_{2i} + \beta_3 X_{3i} + \mu_i$$

Where $\beta_0 = ln\beta_i$, therefore:

$$\ln Y_i = \beta_0 + \beta_2 lnX_{2i} + \beta_3 X_{3i} + \mu_i (2)$$

To linearize the model for the parameters β_0, β_2 y β_3 becomes in a linear regression model. but it is not linearized for Y and X, but it is for the logarithms. It is known as the model log-log, double-log or lineal-log, and it is solved by ordinary least squares.

Economically, the continuous movement rates of the Cobb Douglas function are interpreted as:

β_2, the production partial elasticity respects the labor input, measure the percentual change in the production because of the variation on 1% in the labor input with the capital input constant; β_3, is the partial production elasticity respect to the capital input, with the labor constant; and the adding (β_2 y β_3) are yields in scale, the answer of the production because of a proportional change in the input. If the add is 1, there are constant yields in scale. If the add is les tan 1, there are decreasing yields in scale. Finally, if the add is more than 1 there are growing yields in scale (Gujarati, 2010).

By other side, the growing rates, are useful to determine the growing in the production given changes in the inputs. For example, it can be used (Equation 3):

$$Y = Ae^{rt} \tag{3}$$

This can be expressed as natural logarithm (Equation 4):

$$lnY = lnA + rtlne \tag{4}$$

$$lne = 1$$

Deriving ln Y with respect to the time is gotten the growing rate (Equation 5).

$$\frac{\partial lnY}{\partial t} = r \tag{5}$$

Relating the growing rates and the economic analyzes, $Q_t = S_t + R_t$

Where:

Q_t = Production in the moment t

S_t = Harvested surface in the moment t

R_t = Average yield by hectares in the moment t

To get the natural logarithm (Equation 6):

$$lnQ_t = lnS_t + lnR_t \tag{6}$$

Get the derivative of each variable with respect to the time (Equation 7):

$$\frac{\partial lnQ_t}{\partial t} = \frac{\partial lnS_t}{\partial t} + \frac{\partial lnR_t}{\partial t} \tag{7}$$

The first derivative with respect to the time in the variable expressed in the natural logarithm is its continuous growing rate r (Equation 8).

$$r_Q = r_S + r_R \tag{8}$$

The continuous movement rate in the production is equal to the addition of the the harvested surface and the yield continuous rates (Brambila, 2011).

In this research was used a mix approach (quantitative and qualitative) divided in two phases. La first phase was theory, where documental information from many web sites was analyzed. The second phase was quantitative, where was realized the potentialities of corn production, through the software Excel.

To get the corn productive potential in the period 2000-2022, were done the following steps:

1. To create a data Serie from the year 2000^{th} to 2022^{nd} where is found the harvested surface (difference between the harvested and damaged Surface), white corn grain yield and production in the same period.

2. It was taken the highest value of the harvested Surface and it was multiplied by the maximum yield gotten the productive potential of white corn.

3. It was used the Cobb Douglas to get the elasticities from the harvested Surface and the yields, for that it was linearized the function using the data natural logarithm.

4. One time were gotten the natural logarithms of each data it was realized a linear regression after that it was analyzed (Equation 9).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \quad (9)$$

Where:

Y= Production

X_1 = Harvested Surface in the period 2000-2022

X_2= Yield in the period 2000-2022.

5. After that, the national demand level was gotten by the formula (Equation 10)

$$Domestic\ demand = apparent\ consumption = Production + Imports - Exports \quad (10)$$

The corn domestic demand was compared with the productive potential in the step 2, to determine if is accepted or rejected the planted hypothesis.

3. Results

The production of white corn is the difference between the harvested and the damaged surface in a crop, multiplied by the yield that is the one that is used in this research in a period of analysis from the year 2000 to 2022. Once that the statistics and documental information about the harvested area, yield and production were gotten the potential productive level was calculated. The potential productive is defined as the maximum production gotten to multiply maximum harvested surface and the maximum yield, in the period of time considered (2000-2022), that is 31,790,146.720 tons. This production is over the produced in the last year of the period analyzed, that means that Mexico can produce more than the reported during the last years (Figure 1) (Servicio de Información Agroalimentaria y Pesquera (SIAP), 2023).

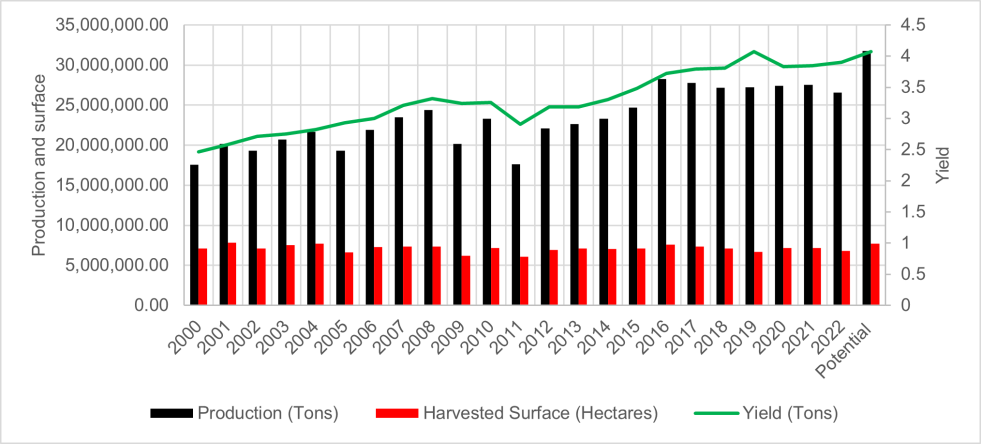
For other side, by a linear logarithm regression is gotten the growth rates from the harvested and the yield surface (Equation 11):

$$Y = -0.070 + 1.0043X_1 + 1.00093X_2 \quad (11)$$

It is observed that the production (Y) at the beginning has negative sign this indicates that in this case there are a slight negative tendency in the growth of maize production, in the analyzed period. For other side, the coefficients of X_1 and X_2, correspond to the growing rates and the harvested surface (X_1) as the yield.

(X_2), also denominated elasticities. They show that the elasticity of the harvested surface is unitary; that means that, when the harvested surface grows in the same proportion as the production does. Likewise, the yield elasticity is unitary, when the production raises in the same proportion as the yield raises.

Figure 1. White maize production in Mexico during the period 2000-2022.



Source: Own elaboration with data from SIAP, 2023.

The determination coefficient (r^2) indicates the proportion of the variability in the independent variable, that is explained by the equation of the regression estimated; it means the Goodness of fit. Therefore, the product of this coefficient by one hundred is the percentage of the variability on "Y", that is explained by the regression equation, in this case 99 %. The production is explained by the harvested surface variable and the yield in 99% (Table 1 and Table 2).

Table 1. Logarithm regression statistics for growth rates

Multiple correlation coefficient	Determination coefficient			
	R^2	R^2 Adjusted	Typical error	Observations
0.99998	0.99997	0.99996	0.00082	23

Source: Own elaboration with Excel software and data from SIAP, 2023.

Table 2. Variance Analysis

	Degrees of freedom	Sum of squares	Root mean squares	F	Critical value of F
Residual regression	2	0.48539843	0.242699214	353954.57	3.23893E-46
	20	1.3714E-05	6.85679E-07		
Total	22	0.48541214			

	Coefficients	Typical error	t statistic	Probity	Inferior 95%	Top 95%	Inferior 95.0%	Top 95.0%
Interception	- 0.07049	0.04660	-1.5127	0.145984474	-0.1677	0.02671	-0.1677	0.02671
Harvested Surface	1.00439	0.00294	341.550	3.85918E-39	0.99825	1.01052	0.99825	1.01052
Yield	1.00093	0.00123	807.367	1.30241E-46	0.99834	1.00351	0.99834	1.00351

Source: Own elaboration with Excel software and data from SIAP, 2023.

The F statistical proof is to verify if the production is related with the harvested surface and if the production is related with the yield. It is observed that the t value for both components is different from zero, that implies that there are a significant statistically relation. Also, analyzing the F proof it can be gotten the same conclusion. Both variables (harvested surface and yield) are significative statistically to explain the production. However, there are not any that dominates over the other; Therefore, the

second hypothesis of research is not accepted, because of the yield of maize is not the variable more determined in the production as was stated.

One time was gotten the productive potential 2022 and the growth rates of the harvested surface and the yield, it was realized the calculus of the apparent consumption for the 2021st year and the white maize demand, the last year reported for the official source. The productive potential was calculated for all the period 2000-2022 (Equation 12).

$$Demand\ (tons) = Apparent\ consumption = production + imports - exports \quad (12)$$

White corn maize in Mexico for the year 2021^{st} = 27, 998, 095.24 tons.

White corn productive potential in Mexico during the period 2000-2022: 31,790,146.720 tons

To compare the domestic demand and the potential demand shows that can cover the domestic demand and get a remaining of 3,792,051.48 tons to export if were done a good use of the available scarce resources producing to the maximum potential surface and the reported yield in the analyzed period. With this, is accepted the first stablished hypothesis because Mexico can satisfy the domestic demand of white corn producing at the maximum potential.

4. Results discussion

The maximum maize quantity by hectare do not produce the maximum rentability, so looking for the maximum yield by hectare do not pays off necessarily the maximum economic benefit that a rational producer of maize would look for to sell in the market (Vargas et. al., 2021); this matches with this research, because of the elasticity of maize production with respect to the harvested surface and yield, was unitary, that indicates that the maize production grows in the same extent that it increases can be the harvested area or the yield, in both cases do not grows the production; also, the production and the rentability only increases in the proportion given by the increasing in the yield, but it is not the maximum rentability.

By other side, in the case of fruit and vegetable products, the production increases more by the yield than by the harvested surface, for example in the case of strawberry during the period of validation (2005-2014), in which the growing rate 7.1 %, distributed between two components: surface and yield.

For this reason, it was inferred that the strawberry production grows more by the technological change than by the increasing of the harvested surface, in the zone of study during the period of the research, for that the planted hypothesis was accepted (Estrada-Chavira et. al., 2017).

In this research the result was different, because in the measure that grows the harvested surface and the yield the production grows in the proportion. That means that, there are not any component that influences more, both grows at the same rate.

Therefore, the strawberry is a fruit considered a product for consumers from medium to high incomes, instead the maize is a basic food in the Mexican population and the commercial value is not compared between them. In this sense, it was determined the strawberry potential, where the increasing was more to the results of this research for the technological component that was the motor of the production, but it is not the case of maize production in Mexico case.

Additionally, previous studies show that the guarantee prices encourage the maize production in Mexico, but in conservative form. To increase the maize supply through yield the government could encourage through higher subsidy in the fertilizer that use the crop (Reyes et. al., 2022). Also, give subsidy to the producers to buy tractors and implements (Aguilar-Carpio et. al. 2021), and not only the guarantee prices stablished nowadays.

5. Conclusions

The components yield and harvested surface analyzed in the production of white maize, there is not one that influences more in the production, both have a unitary elasticity, that means, the production grows in the same proportion as it is included one more unit.

The white maize productive potential goes to 31,790,146.720 tons during the period of analysis (2000-2022). The maize demand in Mexico for the year 2021 was 27, 998,095.2 tons, less than the white maize productive potential calculated. So, Mexico can satisfy the intern demand of white maize and have a remaining of 3,792,051.48 tons to export for the worldwide.

In Mexico is necessary to use guarantee prices also, to complement with other programs as: buying agricultural implements, fertilizers subsidy, among others. In the same way to satisfy the national consumption of white maize grain, is recommended to do a planning for the supply, reordering the offer of the product; that means, to carry the remaining from productive maize zones to the not productive maize zones or the zones that present shortage, through due control of grain by the governmental dependencies implied in the food supply. Also, is recommended a study of transport planning to determine the quantity and routes that would cover the national supply.

Author Contributions

María Eugenia Estrada Chavira: Conceptualization, Investigation, Formal analysis, Writing – original draft, Methodology, Supervision, Validation, Visualization, Writing – review & editing. Maribel Rocío Hernández Velázquez: Formal analysis, Writing – original draft, Methodology, Supervision, Validation, Visualization, Writing – review & editing. Sylja Viridiana Guerrero García: Formal analysis, Writing – original draft.

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