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Analysis of the factors associated with agricultural GDP in Mexico

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ABSTRACT

Objective: To detect factors of production which can explain the total value of agricultural production (agricultural GDP) and to carry out a descriptive analysis.

Methodology: A multiple linear regression adjustment and a descriptive analysis of the variables were carried out, using the available information.

Results: Five variables have a significant association with agricultural GDP. In the last 20 years, the agricultural sector has experienced an exponential economic growth, with a 7.7% annual growth rate (AAGR). About 60% of the total production value is provided only by 7 states. Agricultural exports have increased from 2015, as a result of the USA demands for Mexican fruits and vegetables.

Implications: The information available about the state of agriculture in Mexico makes it possible to understand trends and take actions to increase the agricultural GDP. The analysis is limited by the lack of information about many variables.

Conclusions: Sown areas have decreased and the factors of production analyzed maintain a positive average annual growth rate, which indicates a process of transition from extensive crops (such as grains and cereals) to intensively exploited crops (such as fruits and vegetables). An investment aimed to generate agricultural data is needed.

Keywords: Factors of production, descriptive analysis, average annual growth rate, multiple regression.

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INTRODUCTION

The behavior of the agricultural gross domestic product (GDP) is often related to several variables and factors. Perez-Fernández *et al.* (2018) carried out an analysis taking into account a Cobb-Douglas type model and they found that three explanatory variables shaped the agricultural GDP variations. However, one could guess that more variables would be related to agricultural GDP. Martínez, Salgado, and Vázquez (2017) pointed out that the primary production in Mexico focuses on 30 products, that the agricultural GDP growth has remained lower than the total GDP growth, and that the agricultural sector is highly dependent on the external sector.

Image by Mickael Guyot at Pixabay

At first, it was expected that the variables taken into account had a positive and significant relation with the total agricultural production value. The research hypothesis considers that the trade openness, the use of abundant factors (land and workforce), the technological development of the sector, and the investment in road and highway infrastructures favor the agricultural sector in Mexico. The results matched the original expectations. The trends and behavior of the variables associated with agricultural production must be subject to a periodical analysis, in order to make decisions that support the growth of the sector. This work describes factors that have favored the economic growth of the Mexican agricultural sector during the last 20 years, as well as their evolution. Descriptive analysis of the 14 factors of production related to the agricultural GDP were also carried out.

MATERIALS AND METHODS

The data from the 21 variables used in this study were obtained from several sources. The Anuario Estadístico de la Producción Agrícola del Servicio de Información Agroalimentaria y Pesquera (SIAP) was the source of information for the Agricultural Production Value (PIBA), Agricultural Area (SUPA), Irrigated Agricultural Area (SUPRA), Protected Agricultural Area (SUPROT), and Agricultural Exports (EXP) variables. The "Uso de tecnología y servicios en el campo" reports of SIAP provided the data for the Improved Seeds Use (SUPSEM), Chemical Fertilizers Use (FER), Mechanized Surface (MAQ), Area with Sanitary Facilities (SSANI), and Area with Technical Assistance (ASITEC) variables. FAO provided the open data for the Employment in the Agricultural Sector (POBA), Power Consumption (CE), Diesel Consumption (CEG), Agricultural Researchers (INVA), Spending in Agricultural Researches (GINVA), Agricultural Financing (FINA), and Foreign Direct Investment (IED) variables. The Bank of Mexico provided the data for the Exchange Rate (TC) and the Minimum Wage (SALMIN) variables. The Statistical Yearkbooks of the Secretaría de Comunicaciones y Transportes provided the data for the Road and Highway Infrastructure (INFRA) variable. All the data can be found in the following link:

https://figshare.com/articles/dataset/An_lisis_de_los_determinantes_del_PIB_agr_cola_en_M_xico_/15132120

A multiple linear regression adjustment was carried out in order to find the existing statistical relation between the GDP and the 12 domestic explanatory variables which had enough data to be included in the model. A descriptive analysis of the variables statistically related to the agricultural GDP and some additional significant variables are included in this study. In some cases, the associated quadratic or exponential lineal regression was estimated. This study includes different graphs which were developed using the most informative formats.

A multiple linear regression was carried out to detect the relation between the agricultural GDP and the analyzed variables. The model included variables with enough data to make the estimations; the adjusted model is the following:

$$PIBA = \beta_0 + \beta_1 SUPA + \beta_2 SUPRA + \beta_3 SUPROT + \beta_4 EXP + \beta_5 INFRA + \beta_6 POBA + \beta_7 FINA + \beta_8 TC + \beta_9 IED + \beta_{10} SALMIN + \beta_{11} CEE + \beta_{12} CEG + \varepsilon \quad (1)$$

Where β_0 is the intercept of the model, $\beta_i\, i=1,\ldots, 12$ are the parameters to be estimated, and ε is the error. After carrying out a statistical process to reduce the variables, five significative variables related to agricultural GDP were determined (Table 1): EXP, INFRA, POBA, and CEG have a positive relation to agricultural GDP, while TC has a negative relation. Many non-significative variables in the model have kept a constant growth and, therefore, an association with the response variable cannot be detected, as a result of the lack of fluctuation; however, they can be related with the agricultural GDP.

RESULTS AND DISCUSSION

The agricultural production value largely defines the performance of the sector, because agriculture represents 64% of the agricultural GDP. Figure 1a) shows the behavior of the agricultural production value performance from the year 2000. The 7.7% average annual growth rate (AAGR) did not take into account the inflation. The agricultural GDP had a constant growth since 2000; the model that best fits the data is an exponential model; the estimated equation is shown in the upper part of Figure 1a).

In 2019, the production value of agricultural crops in Mexico surpassed \$675,000 million Mexican pesos. Only 7 states provided 60% of the total amount (Figure 1b): Michoacán (14.31%), Jalisco (11.42%), Sinaloa (9%), Sonora (7%), Chihuahua (6.84%), Veracruz (6.6%), and Guanajuato (4.7%). The states that provide most of the agricultural GDP have a high technification level and a strong crop pattern change aimed to the production of fruits and vegetables.

Multiple Lineal Regression

The model used for this study provided a focus to detect the relation between variables; however, other statical models can be used in further studies, in order to enhance the adjustment of the analyzed data (Table 1).

Descriptive analysis of variables

The variables of the model will be described first. Mexican agricultural exports remained below \$3 billion Mexican pesos until 2014 (Figure 2a). In 2015, \$9,800 million

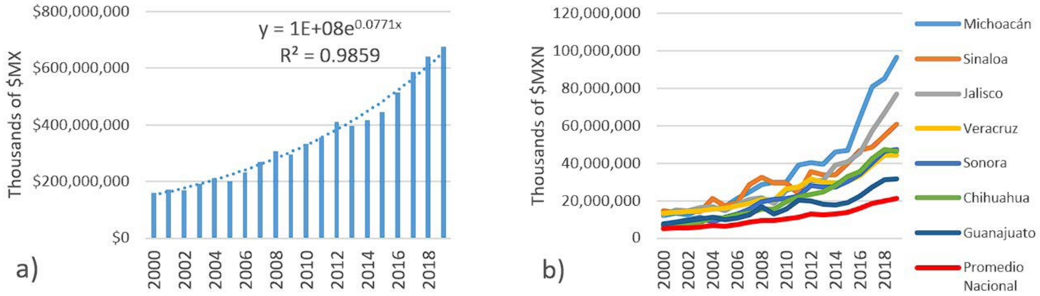

Figure 1. Agricultural production value 2000-2019: a) national and b) local.
Source: Graphs developed by the authors, based on data from the SIAP.

Table 1. Parameters estimation for the adjustment of model 1. Only significative variables are included.

Dependent variable: Agricultural production value (PIBA)					
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**	
(Intercept)	−1.43E+09	1.31E+08	−10.956	2.98E-08	***
EXP	5.77E+00	5.43E-01	10.625	4.38E-08	***
INFRA	1.97E+03	4.67E+02	4.212	0.00087	***
POBA	1.06E+05	1.43E+04	7.448	3.11E-06	***
TC	−1.22E+07	3.78E+06	−3.213	0.00626	**
CEG	4.40E+03	5.54E+02	7.951	1.47E-06	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Mexican pesos were reported, followed by a 107% growth rate in 2016. Since then, a 31% AARG was maintained until 2019, when exports surpassed $46,400 million Mexican pesos. The drastic change that took place since 2015 can be related to the demand for fruits and vegetables from the USA. Figure 2b) shows that the change in the behavior of agricultural exports was mainly the result of the produces grown during the last years, in the states of Baja California, Sonora, Sinaloa, and Michoacán. The main agricultural products exported by Baja California are: tomato, chili, chick pea, squash, and asparagus. It also exports organic peas, mangoes, basil, and other aromatic herbs. In 2017, 4 crops accounted for 56.5% of the agricultural exports of Sonora: table grapes (18.3%), asparagus (14.6%), cucumber (13.5%), and watermelon (10.1%). Sinaloa mainly exports tomato, green tomato, green chili, mango, squash, potato, and cucumber. Finally, Michoacán provided avocado, mango, blackberry, strawberry, and berries for the international market.

The availability of a road and highway infrastructure has a positive influence through production on regional (municipal) economic growth. The effects of the road and highway infrastructure generate regional competitiveness conditions, reducing the implicit transportation costs, diversifying the location, and reducing the concentration in already favored regions (Zepeda-Ortega, Ángeles-Castro, and Carrillo-Murillo, 2019). The length of the national road and highway network (2000-2019) shows a 1.1% AAGR (Figure 2c).

The length of roads and highways increases every year, except when the lack of maintenance affects them to such a degree that some are no longer functional. From 1995 until 2007, employment in the agricultural sector had a downward trend (−1.33% AAGR); on the latter year, a minimum 6,044,000 employments were reported in the sector (Figure 2d). Afterwards, employment demand has increased (1% AAGR). García and Omaña (2001) pointed out that this increase is the result of intensive activities —the increase of the area sown with vegetables and fruits— and extensive activities —the fast growth of the area sown with feed.

During the last years, the exchange rate has been subject to a controlled devaluation in order to favor domestic products in international markets and to attract foreign direct investment. Figure 2e) shows that this policy was mainly used in 1995, 2015, and 2016. The energy consumption of the agricultural sector has doubled during the last 25 years (Figure 2f). On the one hand, 74% of the energy consumption percentage of the sector comes from

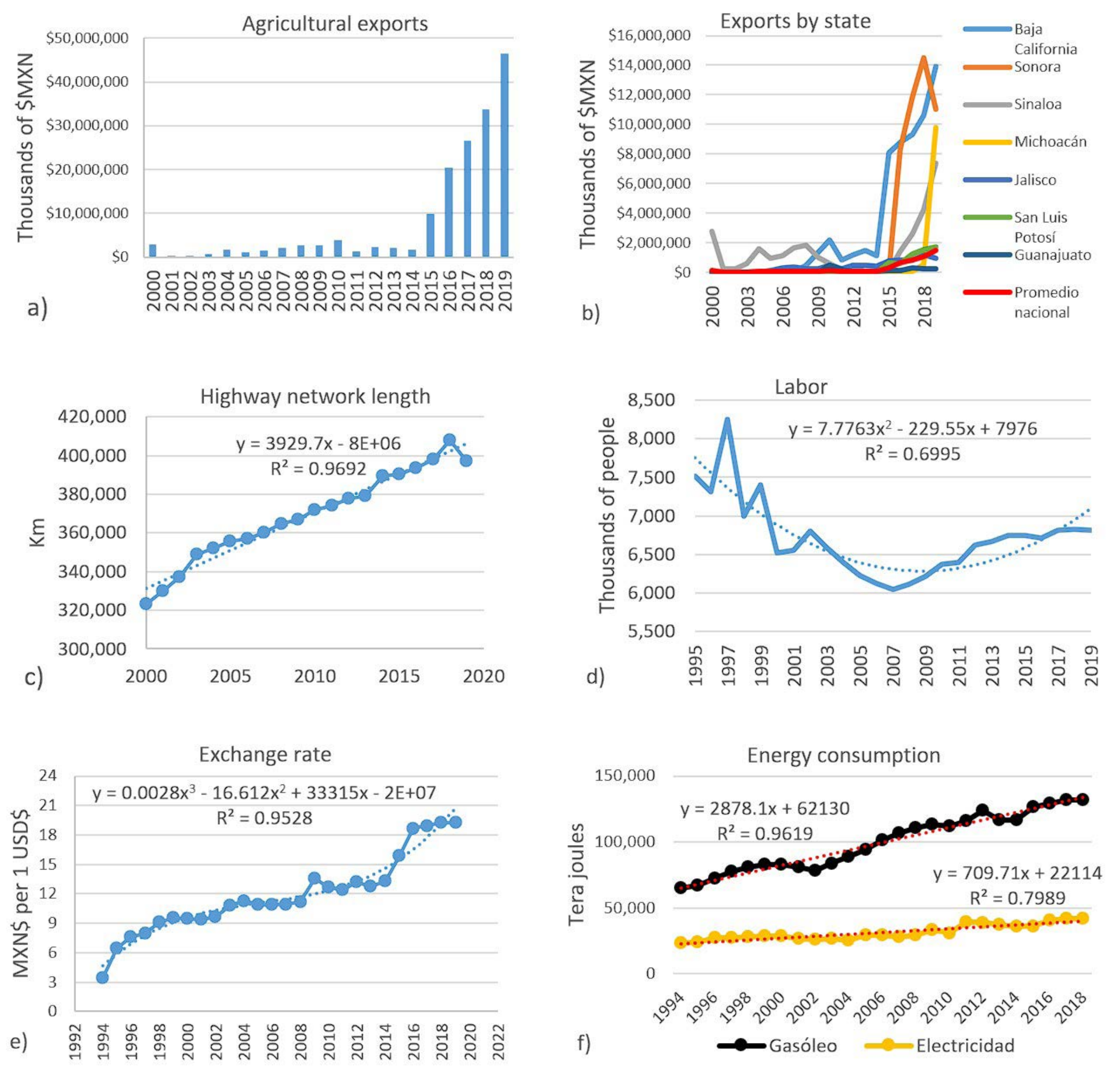

Figure 2. a) Agricultural exports; b) Exports by state; c) Road and highway network length; d) Employment in the agricultural sector; e) MXN/USD exchange rate (1994-2018); f) Energy consumption in agriculture. Source: Graphs developed by the authors based on data from: a), b) SIAP, b) SCT, c) FAOSTAT, d) Banxico, f) FAO.

diesel (CEG); the consumption of this product has increased by a 2.8% AAGR. This fuel is mainly used to pump water for irrigation, to mechanize the field, and to transport harvests. On the other hand, electric power represents 23% of the energy consumption (CEE) and its demand has increased by 2% AAGR. Finally, liquified gas represents 3% of the energy sources.

The agricultural area (SUPA) and the irrigated agricultural area (SUPRA) show a constant behavior (Figure 2a); SUPA has kept an average of 21.7 million hectares. The irrigated agricultural area has increased by 1.22% AAGR, from 4.8 million (2000) to more than 6 million hectares (2019). In 2019, 20.6 million hectares —both short term cyclical crops and perennial crops— were harvested, 29.21% of which had irrigation equipment and 70.89% used rainfed agriculture. The irrigated agricultural area amounted to six million hectares, 62.34% of which are located in seven states: Sinaloa (13.84%), Sonora (9.5%), Guanajuato (8.24%), Chihuahua (9.74%), Michoacán (8.25%), Tamaulipas (7.47%), and Jalisco (5.29%). The demand for irrigated areas in the main agricultural production states has increased during the last 20 years, but not at the same rate as the production value. Protected agricultural areas were recorded as the sum of the greenhouses, the micro-tunnels, and the macro-tunnels. Figure 3b) shows the behavior of the protected agricultural areas in 2000-2019. In 2002, the minimum record reached 75 ha of greenhouses; afterwards, an exponential growth (87.04% AAGR) was reported and, in 2012, the maximum figure of 17,700 ha was recorded. From 2012, the area covered by greenhouses decreased, until it reached 12,400 ha in 2016. Subsequently, the growing trend continued: the 2019 report was closed with approximately 14,200 ha. Greenhouses with medium technology have proliferated in the Bajío region; greenhouses with low technology are mainly located in northeastern and western Mexico (Moreno Reséndez, 2011).

In 2019, 64% of the protected agricultural areas were concentrated in 7 states: Sinaloa (19%); México (11%); Guanajuato (10.4%); Jalisco (8.4%); Puebla (8.8%); San Luis Potosí (4%), and Sonora (2%). The main crops produced in those states were: tomato (70%), pepper (16%), cucumber (10%), and other crops (4%). In 2011, the protected agricultural area in Sinaloa increased to 9,500 ha, although this figure diminished in the next 4 years.

Figure 3c) shows the behavior of the area sown using genetically improved seeds, during the 2014-2019 period; a −1.75% AAGR was recorded, when the harvested agricultural area changed from 49% (2014) to 48% (2019). Fifty-two percent of the agricultural area was sown with native seeds, which were obtained directly from the producers' own crops or from other producers. Maize crops have the largest area sown with improved seeds (4.2 million ha), followed by sorghum (1.7 million ha), and bean (966 thousand ha). Although maize and bean account for the larger areas sown with improved seeds, they are only sown in 60% of the said area. This situation shows the significance that native seeds have for these crops. Taking into account that most of the reported seeds belong to the social programs of SAGARPA (now called SADER) —whose aim was to support small grain producers—, this slightly downward trend, related to a crop pattern change, indicates that the cultivation of grains and oil seeds has been abandoned in favor of feed or vegetables. Tamaulipas, Sinaloa, Zacatecas, Chihuahua, Guanajuato, and Jalisco report the largest areas sown with improved seeds. In Tamaulipas and Sinaloa, 90% of the area is sown with improved seeds. In Oaxaca and Yucatan, improved seeds are used in less than 20% of the area. Tamaulipas and Sinaloa have decreased the area sown with improved seeds, mainly as a result of a decrease of maize and sorghum crops; however, at the same time, they have increased their agricultural production value. This situation proves the pattern change to crops with higher commercial value and higher yields, in terms of value per sown area.

In 2019, 14.8 million fertilized hectares were reported, representing 72% of the total harvested agricultural area. In proportion to the total agricultural area, the fertilized area has kept a 1% AAGR during the last 6 years (Figure 3d). In 2019, the main states with areas fertilized with chemical products were: Zacatecas (9%); Michoacán (7%); Veracruz (7%), and Sinaloa (7%). In 2019, a 15.7-million ha agricultural area was mechanized, which represents 76.3% of the total harvested area (Figure 3e). From 2014, the absolute value of the harvested area has been decreasing, along with the total agricultural area by a

−1.5% AAGR. This decrease suggests that, in some states, less crops which demand large, mechanized areas (maize, sorghum) are sown. The states with largest mechanized areas are the main maize and sorghum producers of the country: Jalisco (10%), Tamaulipas (8%), Sinaloa (7%), Zacatecas (7%), and Chihuahua (7%).

On the one hand, the total agricultural researchers include all full-time researchers, employed by government, non-profit, and higher education organisms in the country. From 1994, an average of 33 agricultural researchers have been hired per year (Figure 3f), which amounted to a total of 3,967 researchers in 2013. On the other hand, the cost of agricultural research has increased by a 2.5% AAGR; in 2013, just above US$710 million

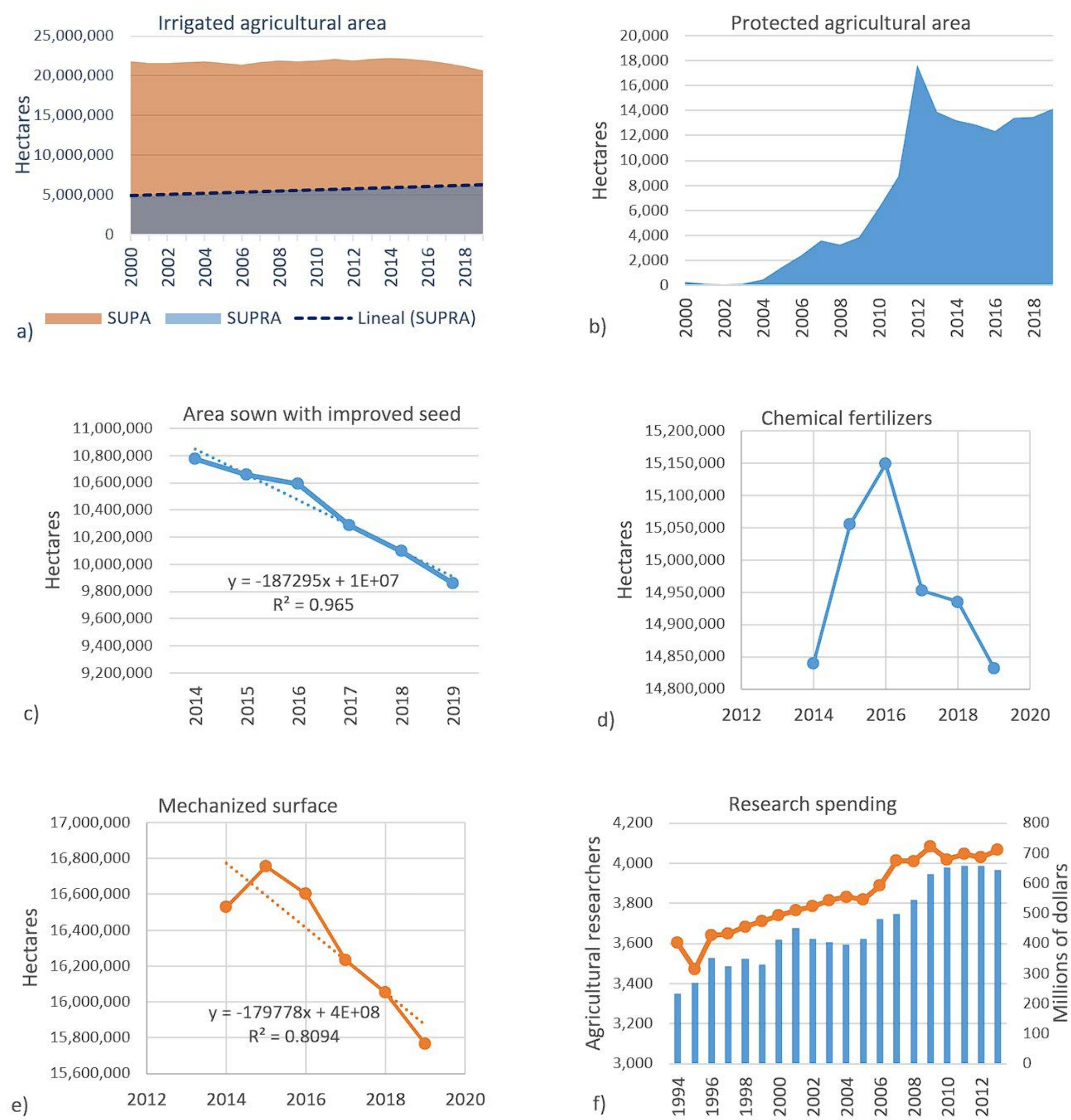

Figure 3. a) Agricultural area (SUPA) and irrigated agricultural area (SUPRA); b) Protected agricultural area; c) Area sown with improved seed; d) Area where chemical fertilizers are used; e) Mechanized surface, f) Agricultural researchers and research spending. Source: Graphs developed by the authors based on data from: a)-d) SIAP; f) FAO.

were allocated for agricultural research. There is no available data about researchers and investment in recent years.

CONCLUSIONS

Factors of production related to the total agricultural production value were analyzed. The increase of the total agricultural production value of the country has a positive statistical relation with the increase of agricultural exports, the development of the length of the road and highway infrastructure, the demand for rural workforce, and diesel consumption. During the last 20 years, the agricultural sector has undergone an exponential economic growth (7.7% AAGR) and only 7 states provide almost 60% of the total production value: Michoacán, Jalisco, Sinaloa, Sonora, Chihuahua, Veracruz, and Guanajuato.

Agricultural exports increased from 2015, as a consequence of the USA demand for Mexican fruits and vegetables. The states with higher exports were: Baja California, Sonora, Sinaloa, and Michoacán. These exports mainly included avocado, tomato, berries, grapes, peppers, cucumbers, and asparagus. The total agricultural area has remained constant during the last years, while the irrigated area has grown by a 1.22% AAGR; 62% of the said area is located in the states of Sinaloa, Sonora, Guanajuato, Chihuahua, Michoacán, Tamaulipas, and Jalisco. Sixty-four percent of the protected agricultural area is located in the states of Sinaloa, México, Guanajuato, Jalisco, Puebla, San Luis Potosí, and Sonora. The road and highway infrastructure is a development engine that connects regions and promotes trade, reducing transportation costs. The Mexican road and highway network has increased by 1.1% AAGR. The demand for rural workforce, the area sown with improved seed, the area fertilized with chemical products, and mechanized area have kept a 1% AAGR. A smaller area with a higher concentration of resources suggests a crop change pattern, which favors intensive export crops (fruits and vegetables) or products that do not face direct competition from imported products (feed). The relative participation of vegetables, fruits, and feed in the total agricultural value has increased.

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