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PRODUCTIVE POTENTIAL: TOOLS THAT CONTRIBUTE TO THE FOOD SOVEREIGNTY OF BEAN (*PHASEOLUS VULGARIS*) IN THE STATE OF MEXICO

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Abstract: The institutional mandate of INIFAP is to generate agricultural and forestry technologies to increase productivity through the productive potential technique. The bean was chosen because it is an important crop in the Mexican diet and the most populated entity, the State of Mexico, and according to the National Population Commission in 2023 there will be 17,500,000 inhabitants. The Rural Development Districts that are of interest for bean cultivation are: Toluca, Texcoco, Tejupilco, Atlacomulco, Coatepec de Harinas, Valle de Bravo and Jilotepec. Two types of productive potential were considered: medium and high. The objective of the work was to determine the productive potential for beans in thousands of hectares to contribute to the food sovereignty of this product in the basic basket of the country's most needy consumers. The methodology for determining productive potential was based on the detection of three categories and nine variables: climate (maximum, average and minimum temperatures and rainfall); soil (depth, texture and pedology) and topography (altitude and slope). The amount of 694.4 thousand hectares susceptible to being planted with this grass were identified with medium and high productive potential. The main DDRs with high productive potential were Atlacomulco with 39.0%, Jilotepec with 20.0%, and Texcoco with 17.4%, between them they add up. almost three quarters (76.4%) of the surface area susceptible to planting with beans. Finally, the detections of these agricultural areas can be included within government programs to support bean producers and thus increase their income levels to contribute to greater well-being and improve their living conditions.

Keywords: high potential, medium potential, production, hectares, apparent consumption.

INTRODUCTION

According to Peter Rosset (2004: 1 p.): *"Food sovereignty is the right of each people to define their own agricultural and food policies, to protect and regulate national agricultural production and the domestic market in order to achieve sustainable development goals, to decide to what extent They want to be self-sufficient, to prevent their markets from being flooded by surplus products from other countries that dump them on the international market through the practice of "dumping"... Food sovereignty does not deny international trade, rather it depends on the option of formulating those policies and business practices that best serve the rights of the population to have safe, nutritious and ecologically sustainable food methods and products."* Heinisch, C. (2013), points out that the concept of food sovereignty was introduced through ``*La Vía Campesina*`` at the Food Agricultural Organization (FAO) Summit against Hunger in 1996 and mentions that it is complementary to that of security. food, a term that appeared in the 70's under quantitative and qualitative aspects.

Beans are essential for the nutrition of the Mexican people and are part of their daily diet along with corn and chili and are part of the basic basket to determine prices and quantify inflation. Its scientific name is *Phaseolus vulgaris* L. and it belongs to the Fabaceae family and is an edible legume both green (bean) and dry (seed), its origin according to Ulloa et al., (2011) dates back to more 5,000 years BC and is found on the five continents and Mesoamerica is considered the center of origin. According to Medina et al., (2016) points out that in Mexico beans are the second most important crop after corn since they are planted on 1,590,876 hectares in the country and of which 85% are planted under conditions rainfed with diverse production systems and in various agroecological regions.

According to the National Population Commission (CONAPO 2023), the State of Mexico is the most populated federal entity in the nation, since it has a total population of 17,500,000 inhabitants distributed in 125 municipalities and in three of them: Ecatepec Morelos, Nezahualcoyotl and Toluca concentrate just over a fifth of their population, who in turn are bean consumers, which is a challenge for the agricultural subsector of the entity to be able to supply this grass that is part of the basic basket. nutrition of the most unprotected population.

For the above, the State of Mexico grows beans on an area of the magnitude shown in Table 1.

At the state level, a clear deterioration is observed in the surface area intended for planting beans, since it was reduced in the period of 20 years by 5.62 times, meanwhile, in 2003, 22,286.00 hectares were planted and only 3,962.22 hectares, in 2022, the evolution of this situation can be seen in Figure 1.

The previous graph shows a trend with a negative slope and the curve that best fits and it is a polynomial type with formula $y = 31.67x^2 - 1538.6x + 21826$ with an $R^2 = 0.9224$ which is considered acceptable. The curve presents six increases in the planted area (years of 2006, 2009, 2012, 2013, 2019 and 2021), which were not enough to stop the sharp decline throughout the period. The decrease in the area planted with beans, when applying the statistical function of the average annual growth rate (AMR), showed in the period of analysis, a negative rate of -8.27% and for the most representative Rural Development Districts in bean planting: Coatepec de Harinas and Zumpango, their rates were also negative at -3.07%, and -11.62% respectively and the six remaining DDRs of the Edo. Mex., are not significant in the planted area of this legume.

With the surface that was mentioned, the production (tons) of beans reached the figures shown in Table 2.

Years	Rural Development Districts								
	Toluca	Zumpango	Texcoco	Tejupilco	Atlacomulco	Coatepec Harinas	Valle Bravo	Jilotepec	Edo Mex
2003	13.00	16,243.00	2,485.00	3.00	123.00	2,815.00	379.00	225.00	**22,286.00**
2004	30.75	13,347.00	2,669.00	18.00	202.00	2,829.00	245.00	210.00	**19,550.75**
2005	27.50	7,689.50	2,546.00	22.00	115.00	2,794.00	263.00	180.00	**13,637.00**
2006	28.00	9,908.70	2,014.00	28.00	105.00	2,794.00	294.00	180.00	**15,351.70**
2007	16.00	9,503.00	1,921.00	29.00	102.00	2,707.00	296.00	145.00	**14,719.00**
2008	6.00	9,547.00	1,730.00	33.00	100.00	2,319.50	192.00	133.00	**14,060.50**
2009	7.00	9,955.00	1,813.00	36.40	91.00	2,111.00	301.00	120.00	**14,434.40**
2010	0.00	8,531.00	1,624.00	37.00	75.00	1,871.50	312.00	90.00	**12,540.50**
2011	10.00	4,636.00	969.00	39.55	72.00	1,914.00	304.00	0.00	**7,944.55**
2012	10.00	6,988.00	879.00	44.69	65.00	1,925.00	349.00	85.00	**10,345.69**
2013	10.00	6,703.00	1,279.00	47.70	79.00	1,874.00	431.00	85.00	**10,504.70**
2014	7.00	6,049.00	999.00	31.55	89.00	1,876.00	457.00	85.00	**9,593.55**
2015	7.00	3,959.00	977.40	34.50	82.00	1.897.50	455.50	87.00	**7,499.90**
2016	7.20	1,754.90	869.22	33.50	35.00	1957.50	361.20	79.00	**5,097.52**
2017	7.00	1,728.37	890.20	18.55	17.00	1,874.60	429.10	73.55	**5,038.37**
2018	0.00	472.70	737.50	18.50	42.00	1,754.80	449.50	51.35	**3,526.35**
2019	0.00	1,851.68	848.21	32.94	37.50	1,895.08	409.61	16.60	**5,091.62**
2020	0.00	1,672.56	740.91	26.90	108.50	1,485.36	348.00	29.25	**4,411.48**
2021	0.00	1,728.85	773.91	27.04	29.00	1,781.57	351.67	33.80	**4,725.84**
2022	5.00	1,374.60	651.65	26.78	47.50	1,509.85	306.34	40.50	**3,962.22**

Table 1. Area planted (hectares) of beans by Rural Development District in the State of Mexico during the period 2003–2022.

Source: SIAP. Sader. Database 2003 – 2022.

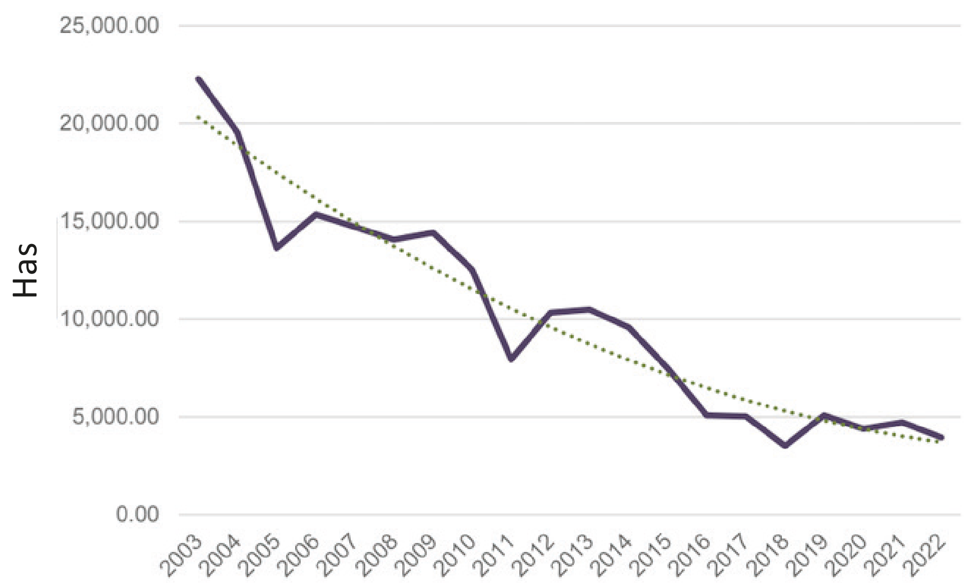

Figure 1: Area planted with beans (has) in the State of Mexico during the period 2003 – 2022 and trend line.

Own elaboration with data from SIAP – Sader, database 2003 - 2022

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Years	Rural Development Districts								
	Toluca	Zumpango	Texcoco	Tejupilco	Atlacomulco	Coatepec Harinas	Valle Bravo	Jilotepec	**Edo Mex**
2003	12.58	15,521.83	2,984.35	1.40	103.20	2,885.10	414.00	168.15	**22,090.61**
2004	32.29	12,356.99	2,638.88	8.64	174.45	2,950.50	308.80	151.25	**18,621.80**
2005	37.31	5,304.20	2,572.02	9.38	102.50	2,725.70	314.10	125.25	**11,190.46**
2006	27.74	8,150.03	2,487.74	11.83	82.60	2,711.20	304.60	109.75	**13,885.49**
2007	15.18	5,284.18	2,496.79	14.64	82.80	2,630.15	299.70	97.50	**10,920.94**
2008	6.00	6,252.75	2,279.40	17.15	73.70	2,385.25	207.20	87.50	**11,308.95**
2009	6.88	4,963.90	2,267.93	16.90	75.30	2,175.41	286.30	58.50	**9,851.12**
2010	0.00	2,436.40	2,235.25	21.19	52.25	1,596.40	271.50	51.00	**6,663.99**
2011	15.35	1,801.61	865.06	19.93	47.40	1,703.21	239.82	0.00	**4,692.38**
2012	30.00	5,016.91	974.75	24.69	44.50	1,591.49	286.60	57.60	**8,026.54**
2013	31.00	5,290.27	1,519.63	25.87	93.00	1,761.55	371.50	62.46	**9,155.28**
2014	7.00	4,974.84	1,203.74	13.63	80.05	2,046.58	395.80	54.45	**8,776.09**
2015	7.35	3,072.49	1,188.46	15.87	73.63	2,339.38	384.45	73.37	**7,155.00**
2016	8.64	1,495.82	1,010.11	17.41	28.50	2,404.23	298.10	74.88	**5,337.69**
2017	10.85	1,145.36	1,017.59	8.85	20.40	2,437.28	433.95	65.14	**5,139.22**
2018	0.00	453.90	844.95	10.93	42.22	2,330.61	518.13	31.45	**4,232.19**
2019	0.00	1,507.11	1,020.02	17.60	40.64	2,364.82	412.81	11.39	**5,374.39**
2020	0.00	1,226.01	834.21	13.19	118.44	1,842.17	337.83	25.07	**4,396.92**
2021	0.00	1,553.48	948.13	12.90	24.40	2,235.80	345.95	26.24	**5,146.90**
2022	7.15	808.28	721.68	13.19	37.75	1,893.60	308.27	32.97	**3,822.89**

Table 2: Bean production (tons) in the State of Mexico by Rural Development District during the period 2003–2022.

Source: SIAP. Sader. Data base 2003 – 2022.

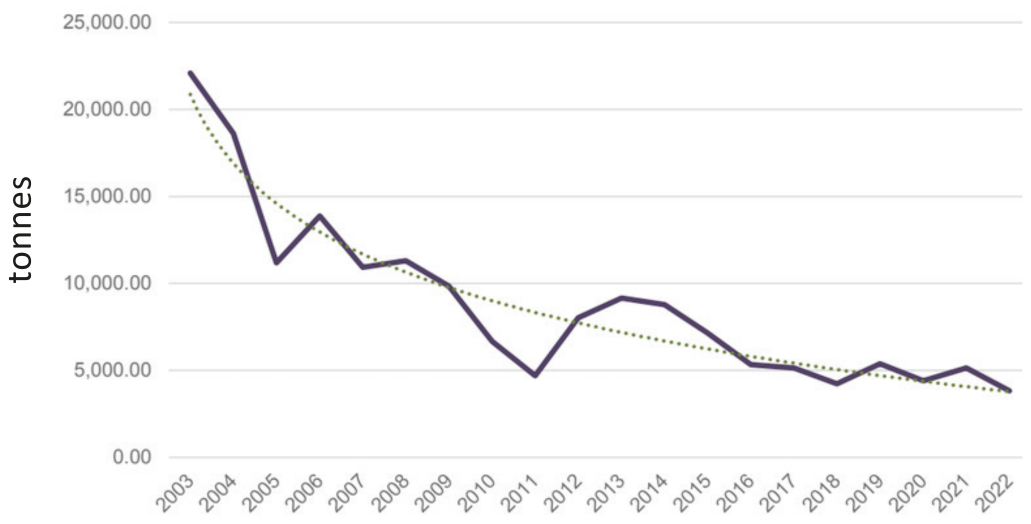

Figure 2: Bean production in tons in the State of Mexico during the period 2003 – 2022.

Own elaboration with data from SIAP – Sader, database 2003 – 2022

The situation that occurs with the area planted with beans is very similar to that of the production of this basic food since the drop is 5.78 times between the year 2003 compared to 2022, since, in the first year of analyzes occurred in the Edo. Mex., 22,090.61, while in the last year only the figure of 3,822.89 tons was reached. The evolution of the drastic drop in production of this product in the basic food basket in the entity is shown in Figure 2.

From the previous graph it is shown that the bean production of the entity has a trend with a negative slope and the curve that best fits is a logarithmic type y = - 5706ln(x) + 20867 with an $R^2 = 0.8941$ which is within the acceptable range. The trend had six increases in bean production (2006, 2008, 2012, 2013, 2019 and 2021), which were not enough to contain the sharp decline throughout the period. The decline in the production of this legume, when using the statistical function of the average annual growth rate (TMCA), presented during the analysis period, a negative rate with -9.80% and for the most representative Rural Development Districts in bean planting: Coatepec de Harinas, Zumpango and Texcoco, were also negative at -2.45%, -15.96% and -9.01% respectively and the four remaining DDRs (Toluca, Tejupilco, Atlacomulco, Valle de Bravo and Jilotepec) of Edo. Mex., are not significant in bean production.

With information from the Funds Instituted in Relation to Agriculture (FIRA 2019) and the Agri-Food and Fisheries Information System (SIAP 1999 2022), they mention that *per capita* bean consumption has a downward trend since, in the 1990s, In the 90's it was 13 Kg/inhabitant, by 2000, it dropped to 11 Kg/inhabitant in 2018, 10.1 Kg/inhabitant was reported, and for the year 2023 a per capita consumption of 7.6 Kg/inhabitant is estimated. With data from CONAPO (2023) they indicate that the population in the State of Mexico is 17.5 million inhabitants, making it the most populated entity in the country. Likewise, the estimated *per capita* consumption of beans for the reference state (consumption *per capita* x population of the State of Mexico), which gives an estimated state consumption of 131,250 tons of beans and with the production that is generated in its Districts of Rural Development (3,822.89 tons) only 2.91% of state consumption is covered and the difference has to be brought from the main producing states such as: Zacatecas, Sinaloa and Durango or through imports with the consequent departure of foreign currency from the country.

The objective of this research work was to determine the productive potential in number of thousands of hectares of beans in the Rural Development Districts of the State of Mexico to contribute to the food sovereignty of the entity of this legume in the basic basket of the neediest consumers. from the country.

METHODOLOGY

The methodological process began with the formation of a multidisciplinary team of three researchers who covered the necessary profiles to carry out the research activities of the project; who are assigned to the National Center for Disciplinary Research in Conservation and Improvement of Forest Ecosystems of INIFAP, with experience in areas of productive potential, agroecology, soils, agroindustries, geographic information systems and economics.

The agroecological requirements for the cultivation of beans were the following: climate, temperature in its maximum, average and minimum meanings, rainfall, soil and topographic variables, altitude and slope, their scales are observed in Table 3.

Layer	Scale	Fountain
Minimum temperature		
Maximum temperature	1:1 000 000	Uniatmos 2019
Medium temperature		
Precipitation	1: 1 000 000	Uniatmos 2019
Edaphology	1:25 000	INIFAP 2001
Types of climates	1:1 000 000	Conabio 2010
Land and vegetation use	1:25 000	INEGI Serie V 2015
Digital Elevation Model	1: 50 000	INEGI, 2018

Table 3: Coverage of agroecological variables.

The potential areas referred to the land suitability classification, as a partial result of the evaluation and grouping of specific surfaces, in terms of their suitability for specific use, which is a function of the ecological requirements of the particular crop and the conditions and characteristics of the sites, variables that condition the bean product system and its production and productivity levels.

To delimit the areas with productive potential in each Rural Development District, the Analytical Hierarchical Process (AHP) developed by Saaty in 1997 was used, which solves complex problems with multiple criteria. Its functionality was structured into three levels: i) hierarchy, which represents the breakdown of the problem into its component parts, ii) establishment of priorities between the elements of the hierarchy and iii) qualification of the relative preferences of the elements, based on a underlying scale, with a scale of values from 1 to 9. Finally, inappropriate areas for growing beans are excluded; the surfaces that were discarded were: bodies of water, protected natural areas, forests, and urban areas.

The multi-criteria evaluation techniques (EMC) to generate fitness levels for bean cultivation correspond to the conjunction of the AHP and the weighted linear combination (WLC), whose continuous criteria (factors) are standardized in a common numerical interval, and then They are combined by means of a weighted average. The hierarchical structure of the criteria and subcriteria that were used are shown in Figure 3.

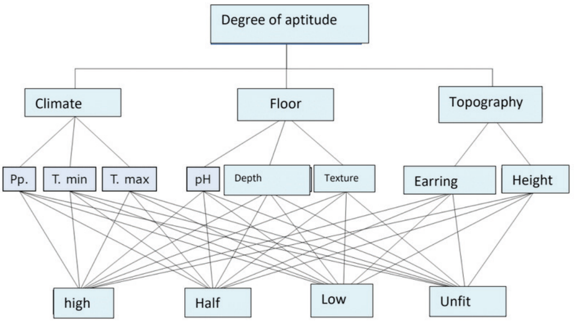

Figure 3: Hierarchical structure of criteria and subcriteria.

Source: Moctezuma et al., (2017) Technical brochure No. 25. Cenid Comef. INIFAP.

RESULTS AND DISCUSSION

As a product of the quantification of the number of hectares susceptible to being cultivated with beans in the Rural Development Districts of the State of Mexico, the productive potential of this legume is presented in Table 4, which is expressed as high and medium.

DDR	Medium PP	%	High PP	%
Toluca	**105,795.27**	39.15	59,509.63	14.03
Zumpango	0.00	0.00	0.00	0.00
Texcoco	17,438.18	6.45	73,652.84	17.37
Tejupilco	6,343.98	2.35	0.00	0.00
Atlacomulco	37,019.11	13.70	**165,212.34**	38.95
Coatepec de Harinas	**57,876.94**	21.42	0.00	0.00
Valle de Bravo	34,557.09	12.79	40,772.74	9.65
Jilotepec	11,218.02	4.15	**84,966.93**	20.04
Total Edo. Mex	270,248.59	100.00	424,144.48	100.00

Table 4: High and medium productive potential in number of hectares of beans by Rural Development District of the State of Mexico

Source: own elaboration with the Cenid Comef database. INIFAP.

From the previous table and in relation to the average productive potential, 270.3 thousand hectares susceptible to being planted with beans were detected in the State of Mexico, the Rural Development District that stands out is that of Toluca in which 105.8 thousand hectares with productive potential were found. that represent more than a third (39.15%) of the average pp in the entity, followed in order of importance by the DDR of Coatepec de Harinas with a little more than a fifth (21.42%), between these two districts there is more concentration of half (60.57 %) of the surface with average pp for this legume, in Zumpango no average productive potential was detected and Tejupilco has a marginal contribution (2.35 %).

Figure 4, as an example, shows a map with the medium and high productive potential of the Toluca Development District of the State of Mexico.

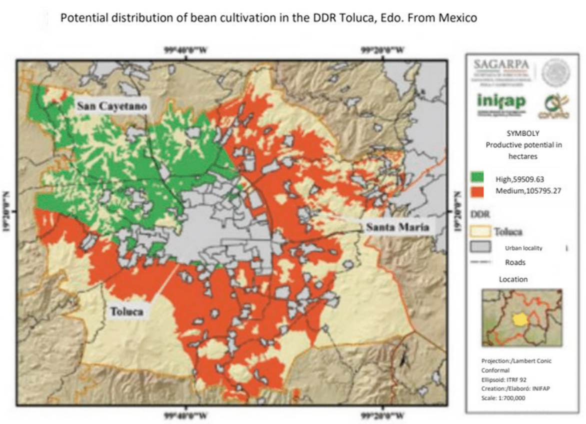

Figure 4. Map of medium and high productive potential for beans in the Texcoco Rural Development District, State of Mexico.

Source. Agricultural Technical Agenda 2017. INIFAP

The previous figure shows the distribution of the medium and high productive potential in the DDR Toluca for bean planting and in which the red areas are those with the medium pp and which surround the city of Toluca in its ¾ parts., concentrating mainly in the southern part of the District and the high pp (in green) surrounds said city from the northern part to the west. The productive potential of the DDR Toluca between medium and high adds up to a surface area susceptible to being planted with beans of 165.3 thousand hectares.

Figure 5 shows as an example, the case of the Atlacomulco Rural Development District, which shows the high and medium productive potential of the Atlacomulco Development District of the State of Mexico.

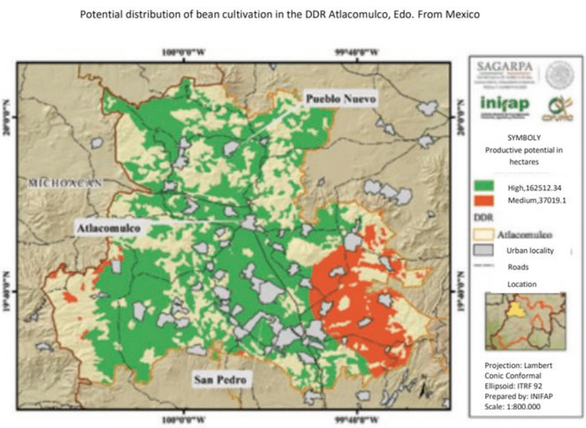

Figure 5: Map of high and medium productive potential for beans in the Atlacomulco Rural Development District, State of Mexico.

Source. Agricultural Technical Agenda 2017. INIFAP

Similarly, the DDR Atlacomulco was the one that presented the largest area with high productive potential (green color) in the State of Mexico and covers almost the entire district except for the southeastern area where the medium productive potential is focused (color red). The productive potential of the DDR Atlacomulco between the medium and the high adds up to a surface susceptible to being planted with beans of 202.2 thousand hectares.

Between the Toluca and Atlacomulco DDRs there is a potential surface area (medium and high) of 367.5 thousand hectares that can be planted with beans, which together represent more than half (52.9%) of the potential surface area for the legume that The State of Mexico is mentioned.

The average yields per hectare (tons/hectare) of beans in their minimums and maximums that occurred in the Rural Development Districts of the State of Mexico under the seasonal modality during the period 2003 - 2019 are presented in Table 5.

District	R min t/ha	Incidence year	R max t/ha	Incidence year
Toluca	0.97	2003	3.10	2013
Zumpango	0.39	2010	0.92	2003
Texcoco	0.90	2004	1.37	2010
Tejupilco	0.42	2006	0.60	2010
Atlacomulco	0.60	2011	1.90	2013
Coatepec Harinas	0.78	2012	1.29	2018
Valle de Bravo	0.73	2016	1.28	2005
Jilotepec	0.49	2009	0.95	2016
Mexico State	0.65	2010	1.15	2018

Table 5: Average yields per hectare (ton/ha) of rainfed beans in the Rural Development Districts of the State of Mexico in the period 2003 – 2022.

Source: SIAP. Sader. Database 2003 – 2022.

From the previous table, it is observed that the lowest average yield per hectare in rainfed beans occurred in the DDR Zumpango in 2010 and the highest yield was in the DDR Toluca in 2013 and the data that was taken into account to infer The contribution to the food sovereignty of this legume was to consider the average of the average minimum and maximum yields in the State of Mexico, which yielded the figure of 0.9 tons/ha. The rainfed production system was chosen because it is the predominant one in bean planting throughout the entity, since, during the analysis period, it occupied an average of 91.4% of the planted area.

Based on Cruz *et al*., (2021), through their generated and adopted technologies, they are reported for different agroecological areas of the country (where the State of Mexico is located), in Table 6 the following varieties are mentioned:

Variety Name	Average yield per hectare tons (*)
Junio León	1.400
Flor de Mayo Eugenia	1.200
Flor de Mayo Dolores	1.500
Negro Altiplano	0.926
Negro Sahuatoba	0.900
Negro Vizcaya	0.900
Pinto Bayacora	1.091
Pinto Mestizo	1.118
Pinto Saltillo	1.139
Salinas	1.000
Pinto Villa	1.723
Raramuri	1.100

Table 6: Varieties generated by INIFAP and recommended for the central region of the country.

*Temporary

Source: Cruz et al., (2021) Technical Book 2. INIFAP.

With the previous parameters of yield and area with high productive potential, the contribution to bean food sovereignty is shown in Table 7.

DsDsR	Sup (has) pp high	R medium/ha	Additional production tons
Mexico State	424,144.48	0.9	381,730.03

Table 7: Estimated additional bean production in the State of Mexico with the high productive power area and the average yield per hectare under rainfed conditions.

Source: own elaboration with data from SIAP and Cenid Comef, INIFAP.

From the previous table it is clear that under the trend of sowing under rainfed conditions the surface that presented high productive potential for the cultivation of beans and with the average yield per hectare that is established in the previous table, the consumption of this food would be covered. of the basic basket at 2.91 times the nutritional needs of the Mexican population and under the assumption that only half of the surface can be planted, 100% of the entity's demand would be covered and there would be a surplus of beans of 59,615.03 tons, which could be used for the consumption of other entities.

Under the scheme that only beans would be planted in the Atlacomulco DDR on its areas of high productive potential and with the same average yield per hectare.

Osuna *et al*., (2012) mentions that in a study of yields with pinto beans in the state of Aguascalientes, the yields under rainfed conditions in 2010, the minimum and maximum were 0.38 to 0.84 tons per hectare and its repetition in In 2011, they were 1.53 t/ha at a minimum and 1.90 t/ha at a maximum and when compared with the estimate of the present study, it was quantified at 0.75 t/ha less. In other parts of the republic, for example, Medina *et al*., (2016) determined that the high and medium productive potential in the states of the northern region and those of Guanajuato were 1,887 hectares, 426 hectares and 6,319 hectares and 789 hectares. has respectively and González *et al*., (2002) points out that for the municipality of Bahía de Banderas in the state of Nayarit for the autumn-winter cycle, favorable areas for bean cultivation were determined in more than 21,000 hectares with high potential that represent 15.7 times more than what is currently planted in that place. Likewise, Moctezuma *et al*., (2022) quantified that in the DDR Cuauhtémoc, Chih, Guadalupe Victoria, Dgo and Rí0 Grande, Zac there are 23,665.5 - 216.8 and 190.8 thousand hectares respectively with high productive potential for bean planting.

CONCLUSIONS

Bean production in the State of Mexico is totally insufficient to cover the demand for this grass, since a deficit is identified in it and under the determination of productive potential in its medium and high modalities in the various Rural Development Districts of the entity, the contribution to achieving food sovereignty of this food from the basic basket of Mexicans is high since, with only 50% of the surface with high productive potential and with a conservative average yield per hectare and temporary, which depends on the amount of rainfall that falls year after year, the needs of demand are covered and surpluses would be generated for marketing in other states of the country and it would contribute to having a less unfavorable agricultural trade balance.

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