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Article

Assessment of the agricultural mechanization index in Mexico in the period 1930-2023

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Abstract

Agriculture in Mexico is increasingly modern and competitive in international markets, so it plays an important role in the growth and development of the country's economy. Mexico ranks twelfth in the world in the production of agricultural crops; this growth, among other factors, is due to technological changes derived from agricultural mechanization incorporated in agricultural production units during the last decades. This research aimed to analyze the current level of mechanization of agriculture in Mexico, as well as to update the national agricultural mechanization index for each state based on data from the agricultural census of 2022. The results indicate that the current mechanization index in Mexico is adequate and, in some states, it exceeds the FAO recommendation of 50 ha per tractor. Support programs from the federal and state governments have been the most important factor in achieving an adequate mechanization index. However, a significant number of existing tractors are about to exceed their useful life, so it is necessary to establish appropriate strategies for their renewal.

Keywords:

agricultural technology, crops, programs, tractors.

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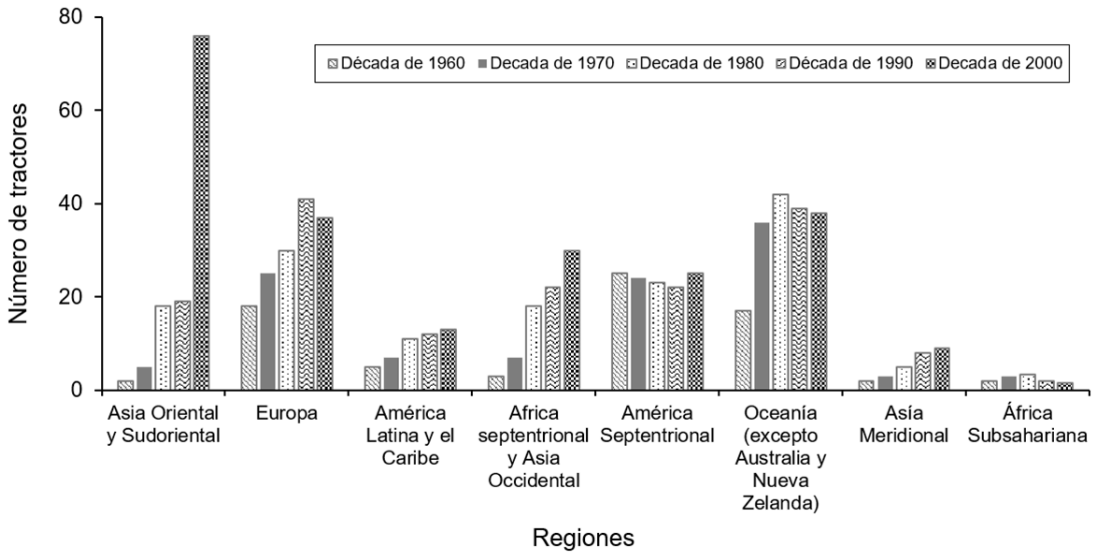
Introduction

Agriculture is a primary sector in the economy and development of any country; according to the Agrifood and Fisheries Information Service (SIAP), for its acronym in Spanish, in Mexico, in 2022, 23 000 000 ha were allocated to this activity, 5 400 000 people were employed, with a production of 273 300 000 t of food and an economic spillover of 885 billion pesos, placing the country as the twelfth largest food producer in the world (SIAP, 2023).

This national competitive level is the product of the technological changes adopted in the various production units, including the mechanization of agricultural processes. Cortés *et al*. (2012) defines mechanization as the use of different machines and equipment in agricultural processes, from preparing the land for planting to harvesting. Agricultural mechanization combined with other technologies, such as improved seeds, fertilizers, and pest, disease and weed management, contributes to improving agricultural productivity and competitiveness, as well as improving work efficiency to produce more and better products (Ulloa, 1989).

The tractor, due to its versatility, is the main symbol to measure the mechanization index, the calculation of which uses basic information on the production area and the number of existing tractors (Aragundi and Pacheco, 2022). According to the Food and Agriculture Organization of the United Nations (FAO); (FAO, 2022), the available statistics on the number of tractors per 1 000 ha of arable land demonstrate the progress towards mechanization in the different regions of the world in the last 40 years (Figure 1).

Figure 1. Tractors in use per 1 000 ha of arable land in different regions of the world (FAO, 2022).



In the case of Mexico, the impulse to mechanization began in the middle of the last century with the implementation of the green revolution and the impulse provided to the acquisition of tractors and agricultural machinery with government support that intensified from the 90s. The signing and entry into force of the North American Free Trade Agreement (NAFTA) in 1994 favored the promotion of mechanization by eliminating import tariffs on agricultural machinery and equipment (DOF, 1997).

The effectiveness of agricultural mechanization depends on the number of agricultural tractors in each country, which implies having an adequate mechanization index (Garrido, 1984); in this sense, FAO (2022) recommends 50 ha of area with mechanizable potential per tractor (Larqué *et al*., 2012).

In this context, the mechanization index in Mexico estimated by Moreno *et al*. (2004) by using the estimate of the agricultural machinery fleet of 180 000 active tractors in 1991 and a planted

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agricultural area of 21 000 000 ha determined a national index of 66.22 ha tractor^{-1}, still above the 50 ha tractor^{-1} recommended by FAO. Therefore, this research aims to analyze the evolution and current level of mechanization of agriculture in Mexico and to update the national agricultural mechanization index for each state of the country. Updating this index is useful to define public policies on the mechanization and renewal of agricultural tractors existing in the country.

Materials and methods

To estimate the evolution of mechanization in Mexico in the different years between 1930 and 2023, the historical statistics of Mexico published by INEGI and the SIAP open database were consulted, and the agricultural area planted, at the state level and by crops, as well as the mechanized area by state entity for the different years were obtained from both data sources.

To identify the number of tractors in operation for the different years, INEGI information from the agricultural, livestock, and forestry censuses carried out in Mexico from 1930 to 2023 was used. It is emphasized that the 1981 census does not present specific information about the use of tractors and agricultural machinery in general, so that year was not incorporated into the analysis.

To quantify the mechanization index, the method used was recommended by FAO, called the mechanization index of area per tractor (MIAT), with an adequate value of 50 ha per tractor (Larqué *et al*., 2012). The existing tractors in 2022, identified in the 2022 agricultural census by the National Institute of Statistics and Geography (INEGI), for its acronym in Spanish, and the average area planted in the last 20 years were considered. This methodology allows us to appreciate the level of mechanization at the national, regional and local levels, the calculation of which was determined with the following equation: MAIT= planted area (A_E) tractors in operation (T_O)$^{-1}$.

The data were processed and analyzed with a spreadsheet of Excel version 2013, with which the values for the MAIT were obtained, a variable that was applied in the state and national levels, which allowed us to determine the behavior of the MAIT in the last 30 years by each state.

Results and discussion

Number of tractors in operation nationwide in the period 1930-2022

The grown area in Mexico at the beginning of the twentieth century sustained accelerated growth, going from 3 500 000 ha in the 30s (INEGI, 2010) to 21 100 000 ha at the end of that century, an area that has remained constant during the 20 years of the twenty-first century (SIAP, 2023). Regarding the number of tractors, the growth dynamics were similar, going from 10 000 tractors (INEGI, 2010) to 473 195 units (INEGI, 2022) in the same period (Table 1).

Table 1. Planted area and number of tractors in Mexico in the period 1930-2022.

Year	Tractors	Planted area (ha)	Mechanization index
1930	10 000	3 513 413	351
1940	16 000	5 913 473	370
1950	76 000	8 576 221	113
1961	110 000	12 336 539	112
1970	115 230	15 128 700	131
1991	240 618	19 183 333	80
2007	238 248	21 733 230	91
2022	473 195	20 664 424	44

Prepared with data from Mexico's historical statistics (INEGI, 2010), the open database of (SIAP, 2023), and the database of agricultural, livestock and forestry censuses, carried out in 1930, 1940, 1950, 1961, 1970, 1991, 2007 and 2022 published by INEGI.

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As for the mechanization index, it increased rapidly in the same period (Table 1); in the 30's, a tractor was operated for every 351 ha of arable land, whereas in 2022, a tractor was used for every 44 ha of arable land. This evolution is the product of the national agricultural policy, marked by the different models of economic growth implemented in the country, moving from a closed economy, at the beginning of the 30's, to an open economy from the 90s, as well as the implementation of a set of programs to support the countryside, among which are the promotion and support for small producers and the program of direct support to the countryside (PROCAMPO), for its acronym in Spanish, alliance for the countryside, and agricultural development program, all of them subsidized the acquisition of tractors (SAGARPA-FAO, 2006).

In general terms, the number of tractors recorded in Mexico grew steadily over the last 40 years as a result of the different government programs implemented and, to a large extent, due to the dynamism of the growth in productivity and competitiveness of Mexican agriculture; this is why for 30 years, annually, around 10 000 tractors have been incorporated into the Mexican countryside, which allowed the mechanization of 80% of the cultivated agricultural area, which today is around 21 100 000 ha (SIAP, 2019), of which 65% of the mechanized area is concentrated in six crops: corn, sorghum, beans, coffee, sugarcane, and wheat (SIAP, 2023). This dynamic also made it possible to replace tractors that have exceeded their useful life, which are 4 905 per year on average (Negrete, 2013).

Number of tractors in operation at the state level in the period 1930-2022

In 1991, there were 240 618 active tractors in Mexico (INEGI, 1991), of which 75% are concentrated in 11 states in the north and center of the country (Table 2). Sixteen years later, the 2007 agricultural and forestry census indicated the existence of 238 248 active tractors in the country (INEGI, 2007); that is, 2 370 fewer tractors, which in general terms represented a negative growth rate of -1%, but different between the states, some with a positive rate and others with a negative rate, which indicates that the new tractors that were incorporated into the Mexican countryside during this period were not enough to replace those that stopped operating because they exceeded their useful life, which is 20 years according to Negrete (2013).

Table 2. Number of tractors in Mexico period 1991-2022.

Num.	States	Year 1991	Year 2007	(%) growth 1991-2007	Year 2022	(%) growth 2007-2022	Num. of tractors that will exceed the useful life by 2030
1	Chihuahua	27 406	26 749	-2	42 260	58	19 560
2	Zacatecas	22 844	24 448	7	53 483	119	12 042
3	Jalisco	19 938	19 907	0	43 462	118	12 168
4	Guanajuato	18 039	21 572	20	37 316	73	9 728
5	Tamaulipas	16 881	12 472	-26	21 008	68	9 780
6	Michoacán	14 190	13 446	-5	33 388	148	7 146
7	Veracruz	13 655	9 396	-31	18 090	93	6 331
8	Durango	12 617	13 447	7	27 957	108	4 570
9	Sinaloa	11 906	17 522	47	37 245	113	7 723
10	Sonora	9 698	8 705	-10	16 826	93	4 628
11	Mexico	9 042	8 479	-6	15 627	84	2 359
12	San Luis Potosí	6 735	7 347	9	15 008	104	3 944
13	Puebla	5 907	6 032	2	15 541	158	1 504
14	Nuevo León	5 756	4 479	-22	6 873	53	1 958

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Num.	States	Year 1991	Year 2007	(%) growth 1991-2007	Year 2022	(%) growth 2007-2022	Num. of tractors that will exceed the useful life by 2030
15	Chiapas	5 201	3 180	-39	5 905	86	1 943
16	Hidalgo	5 101	5 363	5	12 924	141	1 479
17	Nayarit	4 922	4 693	-5	9 382	100	1 779
18	Baja California	4 738	4 753	0	7 855	65	2 755
19	Coahuila	4 561	3 710	-19	6 652	79	762
20	Oaxaca	3 364	3 117	-7	5 740	84	1 184
21	Tlaxcala	2 731	2 765	1	7 650	177	1 061
22	Aguascalientes	2 689	3 922	46	6 719	71%	1 325
23	Morelos	2 417	1 947	-19	3 717	91	253
24	Tabasco	2 185	1 010	-54	2 924	190	613
25	Querétaro	2 165	2 496	15	4 563	83	827
26	Colima	1 712	1 561	-9	2 982	91	977
27	Guerrero	1 496	1 400	-6	3 401	143	305
28	Baja California Sur	1 053	1 344	28	1 621	21	953
29	Campeche	794	2 052	158	4 747	131	855
30	Yucatán	409	184	-55	758	312	61
31	Quintana Roo	302	456	51	1 143	151	121
32	Mexico City	164	294	79	428	46	21
	Total	240 618	238 248	-1	473 195	99	120 715

Prepared with data from the agricultural censuses carried out in 1991, 2007 and 2022 published by INEGI.

During the period 2007-2022 and according to the latest agricultural census carried out in 2022, it is observed that, in the last 15 years, the fleet of tractors in operation practically doubled, reporting 473 195 units, a number that represents an increase of 234 947 tractors compared to 2007, with an annual growth rate of 4.7% (INEGI, 2023). According to Negrete (2006), 360 000 tractors are needed in Mexico to cover 100% of mechanization needs, so this number is exceeded by 113 195 units.

Nevertheless, when considering a useful life of 20 years (Negrete, 2013), 120 715 tractors in the next five to eight years will exceed their useful life, of which it is estimated that an average of 10 000 tractors will be replaced per year.

When comparing the mechanization index obtained with the tractors in operation reported in the agricultural censuses of 1991, 2007, and 2022, it improved, going from a value of 80 ha per tractor in 1991 to 44 ha per tractor in 2022, which allowed the mechanization of 78% of the country's planted area, especially in the north of the country, where producers have large areas and income that allow them to acquire, replace, and profitably use agricultural machinery appropriate to their characteristics.

Evolution of the mechanization index by state in Mexico 1991-2022

The calculation of the mechanization index allows us to show the situation by each state. In the 90s, prior to the great boost in the capitalization of the countryside and the commercial liberalization of the country, Baja California, Baja California Sur, Durango, Chihuahua, Zacatecas, Guanajuato, and Aguascalientes had an adequate index, slightly higher than 50 ha per tractor, and Chihuahua showed the most acceptable mechanization index, with 38 ha per tractor. This was only in 1991 (Table 3).

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Table 3. Mechanization index in Mexico in 1991, 2007, and 2022.

Num.	State	Cultivated area (ha)	(%) Mechanized cultivated area	Index year 1991	Index year 2007	Index year 2022
1	Baja California	173 321.8	119	36.6	36.5	22.1
2	Baja California Sur	37 924.5	117	36	28.2	23.4
3	Tamaulipas	1 236 499	114	73.2	99.1	58.9
4	Sinaloa	1 117 703	110	93.9	63.8	30
5	Durango	670 638.4	106	53.2	49.9	24
6	Sonora	602 947.1	102	62.2	69.3	35.8
7	Chihuahua	1 040 237.6	100	38	38.9	24.6
8	Zacatecas	1 218 268	99	53.3	49.8	22.8
9	Tlaxcala	230 396	98	84.4	83.3	30.1
10	Querétaro	149 410.8	96	69	59.9	32.7
11	Guanajuato	954 096.2	95	52.9	44.2	25.6
12	Mexico City	16 348.2	95	99.7	55.6	38.2
13	San Luis Potosí	798 632.9	92	118.6	108.7	53.2
14	Coahuila	270 555.4	91	59.3	72.9	40.7
15	Aguascalientes	145 511.3	90	54.1	37.1	21.7
16	Nuevo León	332 824.9	90	57.8	74.3	48.4
17	Morelos	139 169.4	89	57.6	71.5	37.4
18	Mexico	765 101	89	84.6	90.2	49
19	Michoacán	1 155 087.9	84	81.4	85.9	34.6
20	Jalisco	1 656 060.2	83	83.1	83.2	38.1
21	Colima	158 960.8	81	92.9	101.8	53.3
22	Hidalgo	537 237.9	74	105.3	100.2	41.6
23	Nayarit	378 906.9	72	77	80.7	40.4
24	Puebla	917 275.2	71	155.3	152.1	59
25	Veracruz	1 509 352.8	63	110.5	160.6	83.4
26	Guerrero	890 613.5	57	595.3	636.2	261.9
27	Campeche	357 582.5	56	450.4	174.3	75.3
28	Oaxaca	1 277 730.5	51	379.8	409.9	222.6
29	Quintana Roo	127 543.2	43	422.3	279.7	111.6
30	Tabasco	255 230.5	34	116.8	252.7	87.3
31	Chiapas	1 333 509.5	21	256.4	419.3	225.8
32	Yucatán	708 374.4	4	1 732	3 849.9	934.5
	Total	21 163 051.2	78	88	88.8	44.7

Prepared with data from the SIAP open database (SIAP, 2020 and 2023) and the database of agricultural, livestock and forestry censuses carried out in 1930, 1940, 1950, 1961, 1970, 1991, 2007 and 2022 published by INEGI.

From 2000, when the federal and state programs for the productive promotion and capitalization of the countryside began, to 2007, two more states, Querétaro and Mexico City, join the aforementioned seven states that had an acceptable mechanization index in the 90s, since the number of tractors in operation throughout the country remained similar, which results from the fact that new tractors replaced those that had already exceeded their useful life.

This year, Baja California Sur had the most acceptable mechanization index, with 28 ha per tractor. In 2022, there is a significant change in the mechanization index in the different states, achieving acceptable indices in 22 of them, which represents 67% of the national total. Campeche,

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Veracruz, Tabasco, Quintana Roo, Oaxaca, Chiapas, Guerrero, and Yucatán showed low levels of mechanization (Table 3), which is associated with traditional agriculture and with high percentages of production for self-consumption.

Nonetheless, when comparing the mechanization indices recorded in 1991 and 2007 of the aforementioned states, their mechanization indices improved compared to these years (Table 3), which suggests that, in these states, progress is being made in mechanization as a result of the programs promoted by the state governments.

Conclusions

The mechanization index in Mexico changed from 351 ha tractor^{-1} in 1930 to 44 ha tractor^{-1} in 2022, as a result of changes in the national agricultural policy. The state that registered the lowest mechanization index was Baja California with 22.1 ha tractor^{-1}, whereas Yucatán registered the highest mechanization index with 934.5 ha tractor^{-1} and in some states, it exceeds the FAO recommendation of 50 ha tractor^{-1}; however, a significant number of existing tractors are about to exceed their useful life; therefore, it is necessary to establish appropriate strategies for their renewal to maintain the appropriate mechanization index.

Bibliography

1 Aragundi, M. A. y Pacheco, H. A. 2022. Índice de mecanización agrícola de la Parroquia Crucita, Manabí-Ecuador. La Técnica. Vi0(4144) . 37-52 pp. https://doi.org/10.33936/la-tecnica.v0i0.4144.

2 Cortés M. E. A.; Álvarez M. F.; y González S. H. 2009. La mecanización agrícola: gestión, selección y administración de la maquinaria para las operaciones del campo. Revista CES Medicina Veterinaria y Zootecnia. 4(2):151-160.

3 DOF. 1997. Diario Oficial de la Federación. Programa Agropecuario y de Desarrollo Rural 1995-2000. https://sidof.segob.gob.mx/notas/4887270.

4 FAO. 2022. Organización de las Naciones Unidas para la Alimentación y la Agricultura. El estado mundial de la agricultura y la alimentación 2022. Aprovechar la automatización de la agricultura para transformar los sistemas agroalimentarios. Roma, FAO. https://doi.org/10.4060/cb9479es.

5 Garrido, P. J. 1984. Implementos, máquinas agrícolas y fundamentos para su explotación. Editorial Científico Técnica. La Habana. 398 p.

6 INEGI. 1991. Instituto Nacional de Estadística, Geografía e Informática. VII Censos Agropecuarios. Instituto Nacional de Estadística, Geografía Informática, México. 4 p.

7 INEGI. 2007. Instituto Nacional de Estadística, Geografía e Informática. VIII Censo Agrícola, Ganadero y Forestal. Instituto Nacional de Estadística, Geografía Informática, México, DF. 29 p.

8 INEGI. 2010. Instituto Nacional de Estadística y Geografía. Estadísticas históricas de México 2009. 22 p.

9 INEGI. 2022. Instituto Nacional de Estadística y Geografía. Estadísticas históricas de México 2009. 11 p.

10 INEGI. 2023. Instituto Nacional de Estadística y Geografía. Resultados Definitivos del Censo Agropecuario 2022. Comunicado de prensa número 667/23. https://www.inegi.org.mx/contenidos/saladeprensa/boletines/2023/CA-Def/CA-Def2022.pdf. 2 p.

11 Larqué, S. B. S.; Cortés, E. L.; Sánchez, H. M. A.; Ayala, G. A. V. y Sangerman-Jarquín, D. M. 2012. Análisis de la mecanización agrícola de la región Atlacomulco, Estado de México. Revista Mexicana de Ciencias Agrícolas. 4(4):825-837.

DOI: https://doi.org/10.29312/remexca.v16i5.3750

12 Moreno, R. D.; Hoyos F. G. y Jiménez, R. R. 2004. Situación de la mecanización agrícola en México. *In*: Memoria del seminario internacional 'la mecanización agrícola y su política'. CENEMA, SADER, JIICA. México, DF. 6 p.

13 Negrete, J. C. 2013. Obstáculos mecanización agrícola mexicana: políticas y leyes de mecanización agrícola. Dictus Publishing. 84 p.

14 Negrete, C. J. 2006. Mecanización agrícola en México. Ed. propia, México, DF. 123 p.

15 SAGARPA-FAO. 2006. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación-Organización de las Naciones Unidas para la Alimentación y la Agricultura. Análisis prospectivo de política de ciencia, tecnología e innovación agrícola. 37 p.

16 SIAP. 2019. Servicio de Información Agroalimentaria y Pesquera. Estadística de uso tecnológico y de servicios en la superficie agrícola. Uso de maquinaria y equipo en la superficie sembrada por entidad federativa 2019. https://www.gob.mx/siap/acciones-y-programas/produccion-agricola-33119.

17 SIAP. 2020. Servicio de Información Agroalimentaria y Pesquera. Superficie sembrada por entidad federativa, según uso de mecanización. Estadística de uso tecnológico y de servicios en la superficie agrícola. Datos según tipo de tecnología empleada en la superficie sembrada. https://www.gob.mx/siap/prensa/estadistica-de-uso-tecnologico-y-de-servicios-en-la-superficie-agricola?idiom=es.

18 SIAP. 2023. Servicio de Información Agroalimentaria y Pesquera. Anuario Estadístico de la Producción Agrícola. Cierre de la producción agrícola. Año 2020-2022. https://nube.siap.gob.mx/cierreagricola/.

19 Ulloa, T. O. 1989. Apuntes de mecanización agrícola. Universidad Autónoma Chapingo (UACH). Departamento de Maquinaria Agrícola. Chapingo, Estado de México. 280 p.

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