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Estimates to determining the agricultural tractor fleet in Mexico

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ABSTRACT

Objective: the objective of the study was to know the current state of the national fleet of agricultural machinery.

Design/Methodology/Approach: an estimate of the tractor fleet was made by adding the number of tractors with one year of lag, plus the number of tractors from national sales, minus the number of tractors leaving the fleet due to the end of their useful life, the period from 2007 to 2027.

Results: there is a downward trend in the tractor fleet in the period 2007 to 2027. If the downward trend continues, the tractor fleet will have decreased by 114 thousand units in 2027, compared to the 238 thousand existing in 2007. This means a drop of 52%, compared to the initial year, which would leave the fleet of tractors with 124 thousand units.

Limitations/Implications of the study: the main limitation is the non-existence of official data after 2007. Therefore, in order to know the current state of the national fleet of tractors in Mexico, estimates such as the one carried out in this investigation are required.

Findings/Conclusions: The estimate of the tractor industrial fleet in Mexico indicates that annually the number of tractors that are added is less than the number of obsolete tractors that leave the fleet, which indicates that the rate of mechanization will decrease in the future. To avoid such a trend, the Government is required to support investments in agricultural machinery.

Keywords: farm machinery fleet, mechanization index, tractor, Mexico.

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INTRODUCTION

Mexico is a country with a land area of 1.96 million km^2, of which 20.6 million ha were used for agricultural land, and more than 550 agricultural products are obtained in different seasons and periods (SIAP, 2019). Agriculture in Mexico is mainly divided into two types of production, traditional and intensive, marked mainly by social and economic differences. Traditional agriculture is generally rainfed and is located, in most cases, in the southern states of Mexico. It is basically for subsistence and is the main source of income for small producers, who do not have the capacity to buy technology or to install infrastructure. Just as they do not have techniques or training for sowing; they only have ancestral ways to cultivate the land that result in low productivity (CEDRSSA, 2017).

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Intensive agriculture, generally irrigated, are large plantations of agricultural products, carried out by agricultural companies whose objective is the commercial production of large volumes. It is generally found in the northern states of Mexico, it uses high-tech infrastructure such as irrigation systems, tractors, modified seeds, as well as hired and trained personnel, since it is more linked to national and international markets (CEDRSSA, 2017).

The evolution of agricultural machinery in the 20th century has been so spectacular that, of the three advances made throughout the history of agricultural machinery, two of them can be considered to mark the beginning and end of the 20th century. The first fundamental advance was recorded when man, who was removing the earth by hitting it with a hoe-type tool, decided to advance with it inserted into the ground to overcome the pulling force. This is how the plow was born at an indeterminate time in prehistory. The construction of the first tractor with an internal combustion engine, due to Froelich in 1892, marks the beginning of the current tractorization. In recent times, electronic and computer devices have been used in machines, which measure diverse variables related to the work they perform, keep the information in records and even decide how the machine should be commanded (Ruiz-Altisent *et al.*, 2000).

The tractor has been an icon of technological change in agriculture, its adoption within the farm has meant various combinations, relationships and established forms of production in a locality, region and country. The dynamics of the tractorization process is defined by the balance given by the units that enter the fleet and by those that are withdrawn due to the end of their useful life (Muñoz *et al.*, 2012).

The farm tractor fleet of a region or country is sometimes taken as an important indicator of investment in agriculture (Muñoz *et al.*, 2011).

The demand for tractors depends, in general terms, on the agricultural activity that takes place in a certain region, a fleet and a greater demand are placed in those agricultural areas where the intervention of man is greater to create favorable conditions to carry out this activity (Mora-Flores, 1986). The level of mechanization of farms is a factor to consider in any technical or economic analysis of the sector, so it is vitally important to have as accurate and detailed knowledge as possible of the national fleet of agricultural tractors (Ministry of Agriculture, Fisheries and Food, no date).

One of the ways to estimate the degree of mechanization of a region or country is through the number of tractors and the intensity of tractorization, measured by power per surface unit (Muñoz *et al.*, 2011).

The inventory of agricultural machinery in Mexico was estimated for the first time in the 1930 Agricultural and Livestock Census, which indicated that there were 3.8 thousand tractors and 8.5 thousand locomobiles in the nation (INEGI, 1936). For 1940, the Livestock Agricultural Census registered 4549 units of agricultural tractors. In 1950 there was a record of 22 711 (INEGI, 1959). By 1982, there were 157 964 tractors (Negrete *et al.*, 2013). The VII National Agricultural Census of 1991 indicated that there were 177 000 tractors and by 2007, according to the VIII Agricultural, Livestock, and Forestry Census, there were 238 000 tractors, of which only 227 000 were in operation. The evolution of the machinery fleet in Mexico had a great growth from 1930 to 1991 according to data from

the Food and Agriculture Organization of the United Nations (FAO, 2021). In 1991 there were 317 thousand units, the highest number ever recorded in the country. Later, in 2007 the number decreased by 79 thousand units, 25% in percentage terms, with a tendency of decrease by almost 5 thousand units per year. In the years after 2007 there is no official record that considers the total number of tractors registered in the country.

According to data from INEGI (2019) reported in the 2019 National Agricultural Survey, of the 100% of the production units that own machinery and equipment to carry out agricultural activities, 65.8% use tractors, 36.4% planters, 28.7% plows, 27.3% disc harrows, 12.1% cultivators for tractors, 6.6% threshers and 0.22% motorized cranes. This is an overview that the tractor is one of the most important elements used in agriculture. One of the most important studies on the number of agricultural tractors in Mexico was conducted by Negrete *et al.* (2013), who made an analysis of the farm tractor fleet in Mexico and estimated 224 thousand tractor units in 2011. Hernández-Ávila *et al.* (2022), in an evaluation of the level of techno-agricultural mechanization in six municipalities of the Toluca Valley, established in their conclusions that the tractor fleet has been in use for more than 15 years, so it is necessary to promote a renewal plan.

Considering the importance of agricultural tractors as one of the most important means of production in the agricultural sector, this study aimed to know the current state of the national fleet of agricultural machinery in Mexico. It is worth mentioning that there are no official data after 2007 indicating the number of active tractors in the country.

MATERIALS AND METHODS

The geographical scope of the study considers the national territory. Due to the scarce statistics on the number of tractors in the country, an estimate of the tractor fleet was made in a time series from 2007 to 2027. The data presented in the VIII Agricultural, Livestock and Forestry Census 2007 correspond to the base year, which presented a scenario of the real existence of tractors in Mexico. This Census reported the total inventory of 238.2 thousand units of agricultural tractors, of which 177.9 thousand had more than 5 years of use and 54.4 thousand had less than 5 years of use. Of the total inventory, only 227.3 thousand were in operation.

To achieve the objectives, the method of Muñoz *et al.* (2011) cited by Negrete *et al.* (2013) was used. This methodology made it possible to estimate the fleet of tractors at a given time, based on the data reported from the last national census of 2007 and with the consideration of the national market sales reported by the manufacturer John Deere from 2008 to 2021.

To estimate the fleet of tractors, the following expression was used.

$$P_t^T = P_{t-1}^T + T_t^N - T_t^R \quad (1)$$

where P_t^T is the fleet of tractors in year t, expressed in units of tractors; P_{t-1}^T is the fleet of tractors with a one-year lag $t-1$, expressed in units; T_t^N is the number of tractors added to the fleet in year t, expressed in y units; T_t^R is the number of tractors leaving the fleet in year t, expressed in units.

The information to estimate the fleet of tractors was obtained from the sources mentioned below. The number of tractors in year $t-1$ was gotten from the VIII Agricultural, Livestock and Forestry Census 2007 (INEGI, 2009). The number of tractors that are added to the tractor fleet were the sales registered in Mexico from the database published by the manufacturer John Deere (John Deere, 2021). The projection of tractors added from 2022 to 2027 was estimated based on the sales of the previous five years. With the data from John Deere (2021), the number of tractors added to the park in year $t-1$ $\left(T_t^N\right)$ was estimated because there is no official, revised and updated record of the number of new agricultural tractors.

According to Muñoz *et al.* (2011), the number of tractors leaving the park (obsolete tractors) can be estimated knowing the average useful life of the tractor, but the difficulty in obtaining this variable lies in the fact that different final figures will be obtained depending on the selected useful life. Muñoz *et al.* (2012) estimated that the estimated average useful life for an agricultural tractor at the aggregate level is 22 years, depending on whether the tractor comes from a certain group of countries.

For the study, the number of tractors leaving the park at time t was obtained from the difference of the number of tractors at time t minus the number at time $t-1$, and the amount added at time t is added, this variable is expressed in units of tractors.

To calculate the number of obsolete tractors, the following expression by Muñoz *et al.* (2011) cited by Negrete *et al.* (2013) and obtained from equation (1) was used:

$$T_t^R = P_{t-1}^T + T_t^N - P_t^T \tag{2}$$

where T_t^R is the number of tractors leaving the fleet in year t, expressed in units; P_{t-1}^T is the tractor fleet with a lag year $t-1$, expressed in units; T_t^N is the number of tractors added to the fleet in year t, expressed in units; P_t^T is the tractor fleet in year t, expressed in tractor units.

The data was processed with Microsoft Excel (2010), with which the values presented in Table 1 were obtained.

The tractor is a symbol of mechanization of agriculture, hence its great importance; it is the main point of reference to measure mechanization indices in the field (Regalado-Negrete, 2006). To calculate the mechanization index, one of the ways is the cultivated area covered in relation to the number of tractors. For this, the formula indicated by Regalado-Negrete (2006) was used. This index shows the intensity of the use given to tractors to implement agricultural operations.

To calculate the mechanization index, the following formula was used:

$$IMi = \frac{SUPi}{TRACTi} \tag{3}$$

where *IMi* is the mechanization index in state i; *SUPi* is the cultivated area in hectares in state *i* and *TRACTi* is the number of tractors in state *i*.

RESULTS AND DISCUSSION

Table 1 presents the results obtained, showing a downward trend in the machinery fleet from 2007 to 2027. From 2008 to 2010 the average decrease is 4 thousand units, similar to that reported by FAO in the 1991-2007 period, 4.9 thousand units. The largest decrease was observed in 2013 and 2020 with around 8 thousand units lost.

If the downward trend continues, the estimate indicates that in 2027, the tractor fleet will have decreased, by 114 000 units, up to 124 000 remaining units (Table 1).

Regarding the tractor fleet, one of the most important studies is the one carried out by Negrete *et al.* (2013), who estimated a quantity of 223 thousand tractors in 2011 and

Table 1. Estimate of the machinery fleet in Mexico, 2007-2027.

Year	Base year	Obsolete	Sales	Park	Annual change
	P_{t-1}^{T}	T_t^R	T_t^N	P_t^T	
2007	238,830				
2008		17,061	15,640	237,409	1,421
2009		17,061	12,985	233,333	4,076
2010		17,061	10,223	226,495	6,838
2011		17,061	10,140	219,574	6,921
2012		17,061	10,630	213,143	6,431
2013		17,061	8,546	204,628	8,515
2014		17,061	9,896	197,463	7,165
2015		17,061	12,899	193,301	4,162
2016		17,061	13,380	189,620	3,681
2017		17,061	14,778	187,337	2,283
2018		17,061	14,401	184,677	2,660
2019		17,061	10,506	178,122	6,555
2020		17,061	8,737	169,798	8,324
2021		17,061	9,613	162,350	7,448
2022		17,061	11,607	156,896	5,454
2023		17,061	10,973	150,808	6,088
2024		17,061	10,287	144,034	6,774
2025		17,061	10,243	137,216	6,818
2026		17,061	10,545	130,700	6,516
2027		17,061	10,731	124,370	6,330
Average 2007-2009		-	-	236,524	-
Average 2025-2027		-	-	130,762	-
GR		-	-	−44.7	-
AAGR		-	-	−3.2	-

GR=Growth rate in the period 2007/09-25/27; AAGR=Average annual growth rate in the period 2007/09-25/27. Source: elaborated by the authors, based on data from INEGI (2009) and John Deere (2021).

extrapolated for 2015, 200 thousand units with the FAO trend model. In this regard, in this research for the same years, the park estimate was 219 thousand units in 2011 (a difference less than 2%) and 193 thousand units in 2015 (a difference of 7 thousand) compared to the above-mentioned report (Negrete *et al.*, 2013).

According to the information reported in Table 1, estimated national sales from 2008 to 2021 were 162.3 thousand units of tractors, an annual average of 11.6 thousand. The year with the highest sales was 2008, 15.6 thousand units; the lowest years have been 2013 and 2020 with 8.5 and 8.7 thousand units sold. The CoVID-19 health crisis decreased sales in 2020 and severely affected the domestic market for agricultural machinery.

The above results indicate that sales have remained stable; these data are similar to those reported by Palacios *et al.* (2003) cited by Ayala *et al.* (2013), who indicated that since 1997 the Mexican market has been very stable in its sales reports, averaging between 10 and 11 thousand tractors per year.

During the period 2007/09-25/27, the growth rate of the tractor fleet was −44.7%, and the average annual growth in the same period was −3.24% in percentage terms, which implies that the tractor fleet has a negative trend in the analysis period.

Table 2 presents a scenario related to the fleet of agricultural machinery by state. It is observed that eight states have the largest number of tractors, Coahuila, Durango, Guanajuato, Michoacán, Jalisco, Sinaloa, Tamaulipas and Zacatecas that altogether have 149 thousand units, which represents 63% of the national fleet.

Considering the number of tractors and the mechanized area per hectare, an estimate of the mechanization index was made. The results show that some states in the Center and North of the country, such as Guanajuato, Zacatecas, Sinaloa, Tamaulipas, Aguascalientes, Baja California and Durango are the states with the highest rate of mechanization with an average very close to 50 ha per tractor. According to Hernández *et al.* (2022), the previous data is the ideal according to what was proposed by the FAO (50 ha per tractor). Some states in the Southeast of Mexico such as Quintana Roo, Yucatán, Oaxaca and Campeche have a rate of mechanization that exceeds 130 ha per tractor. The previous results are similar to those reported by Regalado-Negrete (2006), 70.8 ha per tractor for the northern zone; 221.6 ha per tractor for the southern zone; and 101 ha per tractor nationwide, in a mechanized area of 18.6 million ha.

With a mechanized area of 15.7 million ha in 2019, there is an average national mechanization index of 114 ha per tractor for an index greater than 10% in this study, compared to the national results presented by Regalado-Negrete (2006). The further scenario for 2027 is even more discouraging, because due to 52% decrease in the tractor fleet compared to the base year causes the mechanization index to increase to 219 ha per tractor; this is far from the recommended optimum of 50 ha per tractor.

Gutierrez-Rodriguez *et al.* (2018) made a diagnosis of tractors and agricultural machinery in the municipality of Atlacomulco, State of Mexico, their results showed that in the P. P. Atlacomulco region there are 8.04 tractors per 100 ha, which is equivalent to a mechanization index of 0.08 ha by tractor. This value reflects that there are big differences among the different production areas in the country; there are highly technical areas with agricultural machinery and areas with deficiencies in machinery.

Table 2. Mechanization Index in the agricultural sector of Mexico by state, 2019.

State	Total area	Tractors	Mechanized area 2019	MI 2019	Tractors	MI 2027
	Thousands of ha	Units 2007	Thousands of ha	tractors/ ha	Units 2027	tractors/ ha
Aguascalientes	128	3,922	124	32	2,047	61
Baja California Norte	180	4,753	177	37	2,481	71
Baja California Sur	41	1,344	40	30	702	57
Campeche	340	2,052	271	132	1,071	253
Chiapas	1,360	3,710	278	75	1,937	144
Chihuahua	1,036	1,561	1,033	662	815	1,267
CDMX	16	3,180	14	4	1,660	9
Coahuila	252	26,749	228	9	13,963	16
Colima	162	294	130	442	153	847
Durango	576	13,447	557	41	7,020	79
Guanajuato	948	21,572	876	41	11,261	78
Guerrero	902	1,400	466	333	731	638
Hidalgo	529	5,363	368	69	2,800	131
Jalisco	1,650	19,907	1,517	76	10,392	146
México	747	8,479	643	76	4,426	145
Michoacán	1,119	13,446	1,004	75	7,019	143
Morelos	137	1,947	124	64	1,016	122
Nayarit	370	4,693	265	57	2,450	108
Nuevo León	330	4,479	330	74	2,338	141
Oaxaca	1,254	3,117	613	197	1,627	377
Puebla	939	6,032	741	123	3,149	235
Querétaro	137	2,496	136	54	1,303	104
Quintana Roo	118	456	70	153	238	294
San Luis Potosí	638	7,347	570	78	3,835	149
Sinaloa	1,059	17,522	1,050	60	9,147	115
Sonora	603	8,705	600	69	4,544	132
Tabasco	266	1,010	109	108	527	207
Tamaulipas	1,326	12,472	1,223	98	6,511	188
Tlaxcala	235	2,765	220	80	1,443	153
Veracruz	1,515	9,396	912	97	4,905	186
Yucatán	699	184	31	170	96	325
Zacatecas	1,051	24,448	1,045	43	12,762	82
National	20,665	238,248	15,764	114	124,370	219

MI=Mechanization Index.Source: elaborated by the authors, based on with data from INEGI (2009) and SIAP (2019).

The lack of resources for the acquisition of agricultural machinery and the ignorance of the reality of the problem of the machinery sector, constitute one of the reasons for the lag in terms of the development of agricultural mechanization. The tractors offered in Mexico

are too expensive for small farmers who traditionally practice agriculture; this coupled with the lack of economic resources in cash for the acquisition of new equipment, whose price ranges from 375 to 800 thousand pesos (Ayala-Garay *et al.*, 2012).

In order to reverse the downward trend, in the fleet of agricultural tractors and agricultural machinery in general, it is necessary to encourage an attractive offer for farmers through the granting of credits for the purchase of agricultural machinery. Although there has been support for mechanization, such as the 22 000 tractors granted through the Federal Government from 2013 to 2018 (SAGARPA, 2018) as support for field mechanization, this support is not sufficient for all the agricultural lands in the country. It is necessary to implement better policies focused on the mechanization of the field that help reverse the trend. In order to make it possible that tractors are added to the fleet in greater quantity than the number of tractors ending their useful life.

CONCLUSIONS

The data estimated in this research indicated that the fleet of agricultural tractors in Mexico shows a tendency to decrease. The results of the estimates showed that in the period 2007 to 2027 the number of tractors added to the fleet is notoriously lower than the number of units that leave the fleet. which creates a deficit and a decrease of 114 thousand units in the period.

Estimates indicate that the mechanization index also shows a negative trend. Regarding the mechanized surface in 2019, the index was 114 ha per tractor. The estimate in this research indicates that by 2027 it shall be located at 219 ha per tractor.

The downward trend in the number of tractors makes it necessary to implement credit policies focused on increasing the number of agricultural tractors in the country. Only in this way can the trend in the mechanization index be reversed. Efforts should be directed towards bringing this decreasing index closer to the value recommended by international organizations, which is 50 ha per tractor.

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