

Evaluation of the level of techno-agricultural mechanization in six municipalities of the Toluca Valley

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Abstract

The fundamental objectives of this research were to know the technical state of the park of tractors and agricultural machines, as well as to analyze the technical-economic indices of this park in the six municipalities of the State of Mexico. It was hypothesized that some mechanization indices were similar to or higher than those shown by FAO. To carry out the present work, non-experimental descriptive studies were carried out, since their purpose was to know the current situation of the functionality of agricultural machines, in six municipalities of the State of Mexico (Zinacantepec, Toluca, Metepec, Almoloya de Juárez, Rayón and Calimaya). According to the analysis and evaluation of these results, no tractor exceeds 450 moto-hours of work per year, in addition, the tractor-area ratio in the municipality of Almoloya de Juárez is 12.81 ha tractor⁻¹, being the highest, and the lowest of 4.44 ha tractor⁻¹ in Toluca-Metepec and what is proposed by FAO is 50 ha tractor⁻¹, which shows the degree of underutilization. The implement-tractor ratio is considered optimal, since the lowest for primary soil preparation implements is 0.98 in Toluca-Metepec and the ratio of the other municipalities is greater than 1. Regarding the age of use of tractors, 46% of these were purchased in the period from 2007 to 2017 and 11.2% are Ford tractors, which have an average of 20 years of use, being considered an obsolete farm machinery park.

Keywords: municipalities studied, techno-economic indices, tractors.

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Introduction

Urban growth in the world is an action product of industrialization and the construction of housing and modernization in society, so the reduction in the area dedicated to agricultural activity is accentuated day by day, coupled with a decrease in the workforce in the rural sector and the new activities generated in the industrial and service sector. Agricultural mechanization, measured by the number of hectares of arable land per tractor, was very fast in the period 1965-1981, according to FAO, the number of tractors practically doubled, reaching almost one million units, with notable increases in some countries.

However, the regions of the third world are more irregular in these indices, for example, Africa has 0.6 tractors 100 ha⁻¹; Latin America 0.57 tractors 100 ha⁻¹ and Asia 0.11 tractors 100 ha⁻¹ and the capitalist developed countries (FRG Federal Republic of Germany until 1960) with 16 tractors 100 ha⁻¹, it is logical that this country has an average power of 24.2 kW in its tractors, which increases the density of tractors per 100 ha (Gutiérrez, 1990). According to Johan *et al.* (1991), the mechanization of agriculture has two main objectives: to increase productivity per producer, to change the character of agricultural work, making it less arduous and more attractive.

The analysis of the scenario in the field of agricultural mechanization allows us to state that, in Mexico, from an agricultural frontier with 24 000 000 ha, it has a mechanizable area of 18 600 000 ha, for which around 360 000 tractors with powers of 32, 28 to 44.74 kW (from 50 to 60 hp) are required, if the assumptions of the scenario are valid, the current park would have around 217 300 active tractors, which represents 60% of the mechanization needs (Negrete, 2006). Camarena-Aguilar and Lara-López (2000) estimated 200 000 tractors in 1998 with an average power of 52.5 kW (70.4 hp).

Estimates from the tractor construction industry in Mexico indicate that the park of agricultural machinery amounted to 175 000 tractors in 2003, which work an area of 18 000 000 ha, according to Negrete (2006); Negrete (2011), with a ratio of 102 ha tractor⁻¹. According to INEGI in the National Agricultural Survey (2007), on the percentage of own tractors according to the years of use, the following was obtained: years not specified 7.1%; up to 5 years of use, 16.9%; from 5 to 10 years, 19.7%; from 10 to 15 years, 12.1% and more than 15 years, 44.3%, counting the park of implements and agricultural machines, the following is found: threshers 3.9%; precision seeders 16.7%, implements for soil preparation 29.5%; reapers 2.1%; other machines for agricultural use 47.8%.

According to the PIMA plan for the renewal of the tractor park in Spain, 55% have more than 16 years of operation (Plan PIMA, 2014). Agricultural mechanization, measured by the number of hectares of arable land per tractor, was very fast in the period 1965-1981, according to FAO, the number of tractors practically doubled, reaching almost one million units, with notable increases in some countries. For example, in Venezuela it went from one tractor for every 399 ha in the first five years of the sixties to one tractor for every 94 ha in 1982, while in Mexico, in 1982 there was a tractor for every 148 ha, compared to a tractor for every 346 ha twenty years earlier.

In the sixties, world agriculture had an incorporation of 15 000 000 tractors and in 1982 the incorporation was more than 26 000 000, so from the data obtained, it can be stated that there were 2.1 tractors for every 100 ha of cultivated land (Jróbostov, 1989).

It is here where the study of the productivity of the tractor-machine set has great importance, as an instrument of practical application for the best use of the resources destined to agriculture (Soto, 1983), according to what Ortiz-Cañavate (2010) stated, it is 17 years to carry out the renewal in the Spanish Republic. Agricultural mechanization has had far-reaching effects on agriculture, it has made our agriculture more efficient and more productive, which has allowed our population to be available for other occupations and this has allowed the country to become, from an almost entirely agricultural nation, an industrial power (Soto, 1983).

It is necessary to show, according to some researchers, the hours of work per hectare for some crops in the Mexican Republic: according to Cadena (1997); Reina (2004); Slater (2008), they state that, in Mexico, the average real time of land preparation, sowing, fertilization, pesticide application and crops is approximately 14 h ha⁻¹. These data from Reina (2004); Slater (2008) were used by Negrete *et al.* (2013) to make a comparative state with what was studied at the national level, which was also used for these municipalities subject to the research.

Agricultural mechanization takes place under special conditions and some of its factors cannot be controlled by man. This constitutes a limitation, unlike industry, agricultural work cannot be distributed over time or at will, or uniformly. It is necessary to carry them out at certain times depending on the season of the year, the weather conditions and the soil, factors that in most cases cannot be fully controlled by man and that will affect the economy of the farm. These have different specificities, in the same way, different varieties of plants within the same species do not manifest the same behavior, which affects in one way or another on agricultural mechanization (Iofinov, 1984).

Materials and methods

This research is based in turn on research work that has been carried out in the municipalities: Toluca, Zinacantepec, Metepec, Almoloya de Juárez, Calimaya and Rayón, by thesis candidates of the bachelor's degree of Agricultural Engineer in concomitance, in research projects authorized by the Autonomous University of the State of Mexico, for the purposes of this evaluation-research, it is called 'Regional techno-agricultural pole of the Toluca Valley'.

To carry out this work, field visits were made to small producers, owners of agricultural tractors and machines and the information was obtained through a questionnaire applied to the main communities of the different municipalities. The sample sizes were made based on the calculation of the following formula (Aguilar-Barojas, 2005).

$$n = \frac{N\sigma^2 Z^2}{(n-1)e^2 + \sigma^2 Z^2}$$

Where: n = is the sample size; N = population size; σ = standard deviation of the population, usually when its value is not available, a constant value of 0.5 is usually used; Z = value obtained by confidence levels. It is a constant value that, when its value is not available, is taken in relation to 95% confidence, which is equivalent to 1.96 (as most usual), or in relation to 99% confidence, its value is equivalent to 2.58. These values are taken at the discretion of the researcher, where e - is the acceptable limit of sampling error, usually when its value is not available, a value that varies from 1% to 9% is usually used, a value that is at the discretion of the researcher. The aforementioned municipalities, object of study (Figure 1), are located in the Toluca Valley, in the central zone of the State of Mexico.

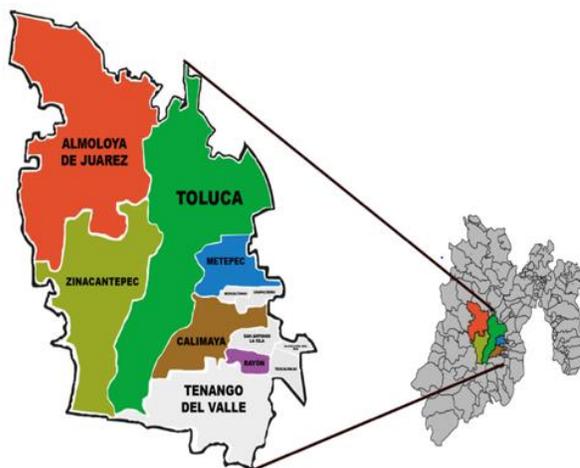


Figure 1. Municipalities studied with images from the Government, State of Mexico.
<https://www.ipomex.org.mx/recursos/ipo/files.ipo/2016/118/6/c91bcfac7e0d4838954ca892517a4087.pdf>.

In each of the research works, the following methodology was carried out: non-experimental descriptive, descriptive transactional studies, because their purpose was to know the current situation of the functionality of agricultural machines, in particular tractors. The cross-sectional study is a frequently used research design. These are observational studies, and aspects related to the population studied have been considered, the subjects or companies from whom the information was obtained were voluntary. For the collection of data, a matrix-type instrument was applied, previously designed, which allowed to statistically describe the variables of: name and type of producer, location, type of crop, area, type of agricultural machine, brand, model, power, number of agricultural implements or accessories, maintenance program: preventive or corrective, technical preparation, crops, agricultural area, age of the tractors, number of agricultural implements and machines, etc.

To obtain the required information, it was based mainly on the conduct of ad hoc surveys (questionnaires) applied directly to farmers, owners of tractors and agricultural machines, in the same way, information was requested from the Secretariat of the Countryside of the Government of the State of Mexico (SECAMPO, for its acronym in Spanish) and the municipal authorities, delegates and members of the ejido commissariat by municipality researched. Before surveying the farmers in the six municipalities, the size of the samples was calculated, according to the formulas proposed by Aguilar-Barojas (2005).

With the results obtained by each municipality, it is intended to explain the competitiveness of agricultural machines in tractors from economic theory in general. The methodology applied is based on the recognition of primary units, called agricultural producers, and the global economy to explain the functioning and operation of agricultural tractors with the dynamics of reality. The scope of the socioeconomic impact that is intended to be achieved through the knowledge of the balance of the machine-tractor set, which leads to an optimal ratio in order to increase the productivity of labor and thereby make their economy greater, giving it a more rational use of their machine-tractor set.

The indices analyzed in this evaluation follow a pattern of the following authors: tractor purchase dynamics in the last 10 years, area-agricultural tractor ratio, number of agricultural machines by type, number of tractors depending on their power, number of tractors depending on their running system, number of tractors by brand.

For the study, the indices proposed by the following researchers were taken as a reference: Karpenko (1989); Gutiérrez (1990); Larqué-Savedra (2019). When the sample size was obtained, the number of farmers to be sampled was selected with the use of a simplified random method, who would always be owners of tractors and agricultural machines. The characterization of the level of mechanization for the aforementioned municipalities was carried out based on the number of agricultural tractors and their different powers, number of implements for each of the tractors surveyed, index of energy equipment, etc.

The formula used in each of the studies was always the same, being adapted to the sample size determined based on the technical-economic characteristics of each municipality. The sample size was calculated based on a minimum unit and the chosen communities were taken at random, with a confidence level of 95%, and 9% was taken as a limit of sampling error, and to calculate the sample size, the finite population formula when the total of observation units that integrate it are known was used, proposed by Aguilar-Barojas (2005). With the results obtained in each of the research works, called municipalities, they are analyzed and evaluated together through descriptive statistics.

Results and discussion

This research work showed the agricultural mechanization in six municipalities of the Toluca Valley in the last 15 years, with the aim of knowing what has been the evolution in this important sector, as well as the importance of the technical and technological level of agriculture in this region of the State of Mexico. Therefore, statistics on the park of machines and tractors are presented, product of 429 surveys carried out in total in the six municipalities under study. Therefore, the values shown in this paper are supported by these surveys directly with the owners of tractors and agricultural machines.

Figure 2 shows the number of tractors surveyed and that approximately give a real sample, since these calculations were made based on calculation formulas shown in the methodology of the work. It is observed that the municipality of Metepec has the least number of tractors and the largest number surveyed occurred in the municipality of Almoloya de Juárez.

Although the municipalities of Zinacantepec and Calimaya have a large number of tractors. Given the extension of the area used in cultivation work in hectares and the number of tractors as a whole, it yields a ratio of approximately $15 \text{ ha tractor}^{-1}$, a fairly small amount, taking into account that FAO proposes approximately 50 ha/tractor (FAO-FAOSTAT, 2017).

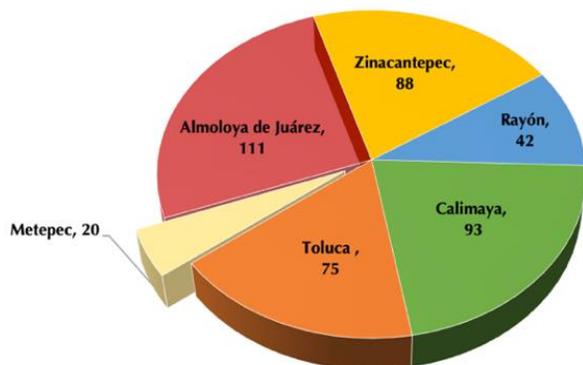


Figure 2. Number of surveys conducted (producer-tractor), by municipality analyzed based on sample calculations, carried out from 2017 to 2019.

In this aspect, according to Palacios and Ocampo (2012), in the south of the Mexican Republic this ratio is $221 \text{ ha tractor}^{-1}$, in the center $104 \text{ ha tractor}^{-1}$ and the index reported for the north of the country is $70.8 \text{ ha tractor}^{-1}$, as can be seen in these data, in all cases, the area is greater than the tractors available, it is important to note that in the province of Manabí, Ecuador, the average area used per tractor is $48.8 \text{ ha tractor}^{-1}$, being, in this case, close to the recommended $50 \text{ ha tractor}^{-1}$ (FAO-FAOSTAT, 2011).

It is important to note that, despite the development that many countries currently have, mainly in precision agriculture, in 90% of corn seeders, there are no those that can have precision equipment attached, and the introduction of signal emitters as well as the GPS technique in tractors has not yet begun.

Another important index to consider in these municipalities is the power per hectare, which as a whole is more than 2 kW ha^{-1} , but in some municipalities, it is much higher than this figure, since the municipality of Zinacantepec has an average of 7.2 hp ha^{-1} (5.29 kW ha^{-1}), well above the national average, which, according to FAOSTAT (2011), is 1.04 hp ha^{-1} . Now, according to studies carried out by Gaytán (2007) of the Department of Mechanical Engineering of the UACH, the power/area ratio that is close to the ideal should be 1 hp ha^{-1} , Palacios and Ledesma (2012), it is necessary to point out that this index, shown in the municipality of Zinacantepec, is well above than that shown in the province of Manabí, Republic of Ecuador, which is approximately 2.28 hp ha^{-1} , according to Loor-Sácido *et al.* (2019).

Figure 3 shows the number of tractors available in each municipality (years 2017 to 2019), it is observed that the largest number of tractors of greatest power is in the municipality of Calimaya and the other municipalities are below this power, according to what was researched by Ortiz-Cañavate (2010), in the Spanish Republic, the average power of the tractors is approximately 120 cv ($\approx 85 \text{ kW}$ and it is necessary to point out that $1 \text{ hp} \approx 1.014 \text{ cv}$); however, the municipality of Calimaya has an average of 91.7 hp , that of Almoloya de Juárez an average of 83.6 hp , these municipalities being the

most developed and with the largest number of tractors, they do not approach the power reported by this researcher, according to what was researched by Negrete (2013), the average power per tractor in Mexico is 52.19 kW (70 hp) and although these municipalities are above the national average at the time of these data are released, it is necessary to increase the power, taking into account the aging of the existing tractor park, which will be analyzed later.

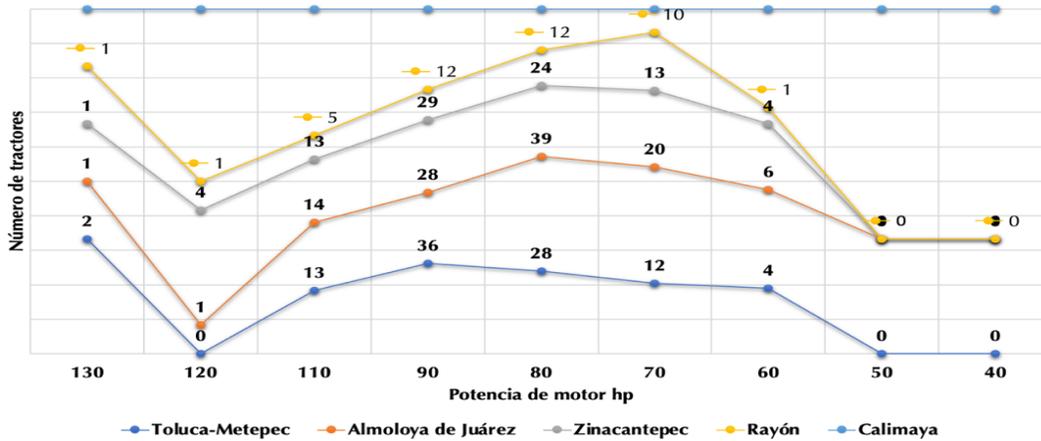


Figure 3. Number of tractors-power in the motors.

The number of tractors that have been acquired by farmers since 2006 (Figure 4) is not significant and, as can be seen, in some cases it has been decreasing, with rare exceptions, but the most important thing of all that has been mentioned is that a large number of tractors were acquired before 2006 and they are quite significant figures, because they show that tractors have been in use for years, which puts them within the possibilities of change for more modern technologies, since these are not in accordance with the scientific and technical achievements in this branch of agriculture, which is agricultural mechanization, it can be mentioned that the municipality of Calimaya has 46% of tractors in use prior to 2006, the municipality of Rayón has a tractor park of 83% prior to the date indicated, Almoloya de Juárez with 33% and the youngest tractor park is that of Zinacantepec with 15% used since before 2006.

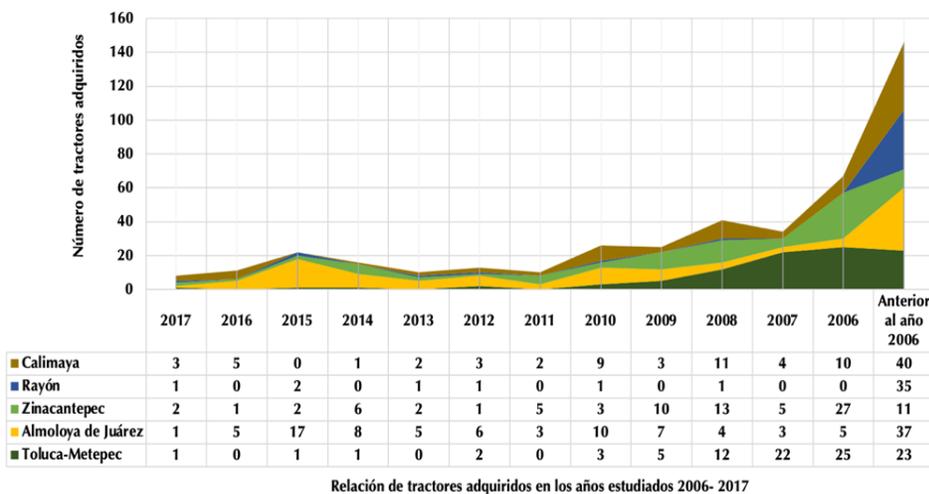


Figure 4. Number of tractors acquired by year in the municipalities studied.

It can be assured that the sale of tractors has been rather an expansion market and not a replacement market in the Toluca Valley, so it is necessary to pay attention to the tractor replacement market in the entire the valley, because what is being presented is nothing more than a sample of what is happening in the other municipalities of the State of Mexico. Therefore, it is necessary to implement plans that help farmers to renew this park of agricultural tractors to make the field more competitive and in turn eliminate tractors that are obsolete and that do not comply with the current technical means that meet the pollution standards and that are also adapted to ergonomic conditions that take maximum care of human health.

In order for the government to establish a plan for the renewal of this park of obsolete tractors, a whole series of objectives must be met, such as: a) that the new tractors are approved; that they comply with all official Mexican standards, before their use; b) that they produce a lower environmental impact than the one they are replacing; c) that are more efficient in the use of energy, eg. $g\ kW^{-1}\ h^{-1}$, and that these have a maximum limit and those that have a consumption greater than that established cannot be marketed; d) that the tractors have more advanced technologies than the previous ones; and e) that the sellers of tractors are obliged to give a course of maintenance, driving and conservation of not less than 15 h to each farmer.

To give a more complete idea of the situation of the park of machines and tractors in each of the municipalities, Figure 5 is shown with the respective table of the number of each of the different implements and tools they have. The municipality of Calimaya is the one that has the highest number of implements, with an implement-tractor ratio of 6.07, this being a fairly high ratio in relation to the other municipalities, since the next is Almoloya de Juárez with a ratio of 5.24 implements per each tractor and, according to what was proposed by Iofinov (1984), this is a good ratio, which can complete most of the tasks that are required on an agricultural farm.

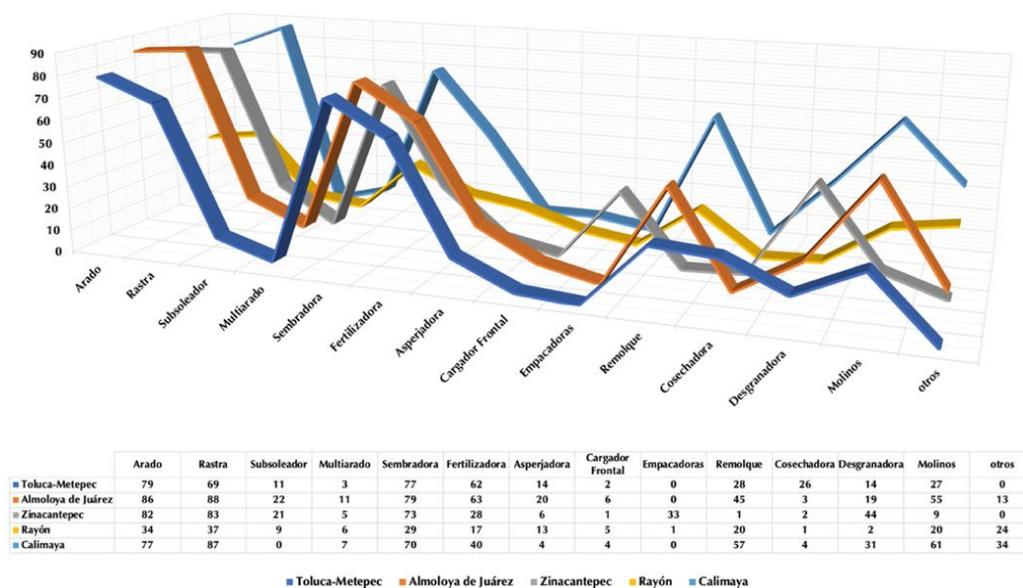


Figure 5. Number and type of agricultural machines by municipality.

The other municipalities are below the aforementioned ratio, since Rayón has a ratio of 4.59, the ratio of Zinacantepec is 4.56 and finally the Toluca-Metepec binomial has a ratio of 4.16 (Figure 6).

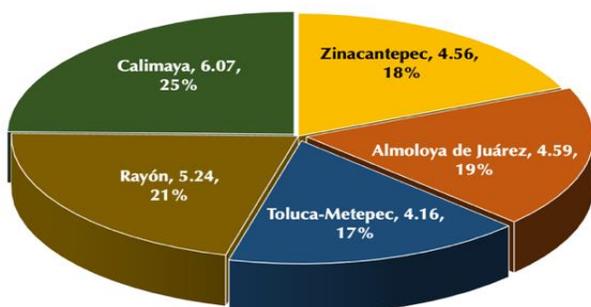


Figure 6. Tractor-implement ratio, municipalities studied, period 2006-2017.

Figure 7 shows the number of tractors that each municipality has and their traction scheme or running system, which is of vital importance for the different works for which they are intended, because as is known, in tractors with a 4 x 4 running system, there is an increase of approximately 35% traction with respect to agricultural tractors with a 4 x 2 traction scheme (ASABE EP496.3, 2006). And as observed in Figure 7, the list of tractors and their running system in the municipalities surveyed show that tractors with a 4 x 2 running system are predominant over those with 4 x 4.

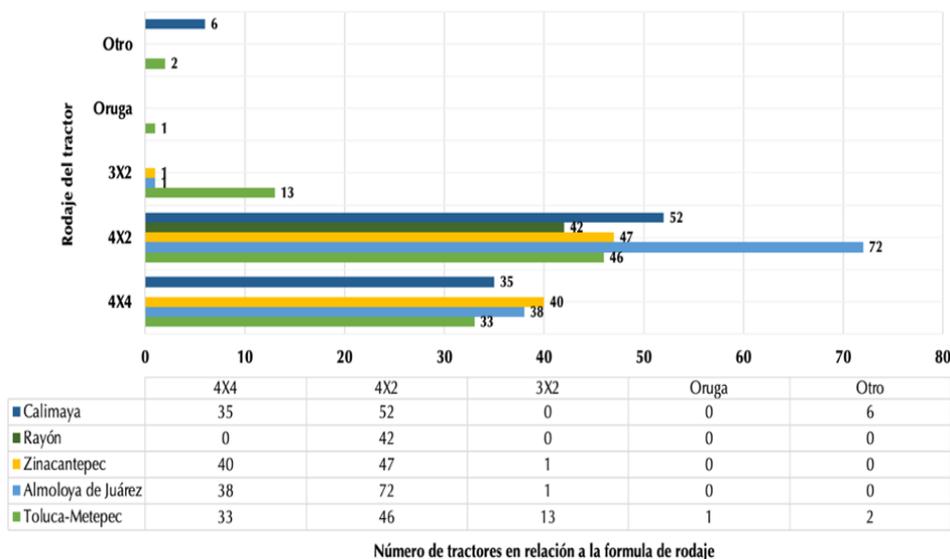


Figure 7. List of tractors and their running system.

In the municipalities Toluca-Metepec, 34.7% of the tractors are of the 4 x 4 system, in Almoloya de Juárez, 34.2% is of this same system and in the municipality of Zinacantepec, it is 45.5% and, for example, in the municipality of Rayón, no tractor with this traction scheme was found and as Morelos *et al.* (2009) state, when comparing these two schemes, there are advantages in the tractor with a 4 x 4 traction scheme, when calculating slipping and traction forces.

It is important that, when choosing a tractor, the running system for the work that is required on the farm can also be chosen, as tests carried out by Romantchik-Kriuchkova *et al.* (2015) showed, in different types of indices in agricultural mechanization tasks with the same model of agricultural tractor with two different running systems (4 x 4 and 4 x 2), such as slipping on the rear wheels, traction potential, hourly fuel consumption and specific consumption, a great superiority in equal conditions in tractors with a 4 x 4 system, and in this case in what was more important, in the values shown in the productivity or field capacity, so it must be taken into account by the owners and by the state government in their plans for the sale of tractors and renewal of the park that the tractors are of the appropriate power depending on the areas that the farmers have and that these have double traction and thus be able to have greater efficiency in the work carried out.

In this analyzed area of the Toluca Valley, it is observed that the driving force in the sale of agricultural tractors has the John Deere brand as a leader in all municipalities and only in the municipality of Toluca and Metepec, the Massey Ferguson brand is above. It is important to note that, in tractor-producing countries, such as Germany, the John Deere brand is marketed above local tractors, similar cases are Bulgaria, France, all this until 2017, something that does not happen in countries such as Austria, Croatia, Denmark, etc., where this brand becomes almost unnoticed, giving way to tractors and agricultural machines of European production.

It is interesting to know, through these data, that, in this region, there are no tractors that have a high quality and that in other countries have taken the leadership from such prestigious brands as New Holland or Massey Ferguson and, in this case, the Japanese brand Kubota is worth mentioning. In addition, as has been observed in the data obtained, the purchase of tractors in the last five years has been very small in this area analyzed (<https://www.interempresas.net/agricola/articulos/210018-convulsion-en-los-mercados-europeos-de-tractores.html>).

It is necessary to limit that, until 2017, most countries had a growth in the purchase of tractors and harvesters, because at this time, for example Norway had an increase of 7.5%, Poland of 21.2%, Portugal 13.8%, Argentina 22%, the United States of America 4.5% and, in tractors of more than 100 hp, there was a fall of 8.1%; however, in the Toluca Valley in the municipalities analyzed, the fall in the purchase of tractors has been quite noticeable when observed in Figure 8, with the exception of Almoloya de Juárez.

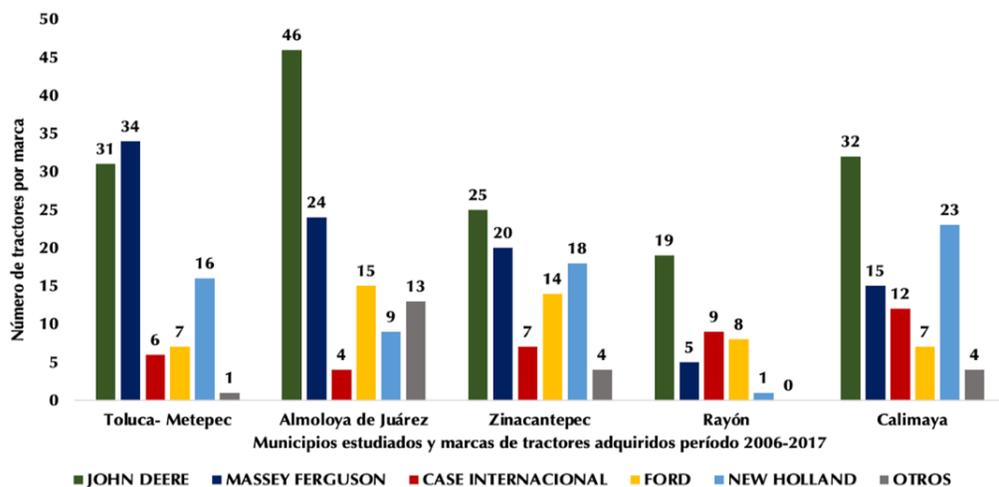


Figure 8. Brand of the tractors acquired (surveys), period 2006-2017.

Conclusions

The study carried out in these six analyzed municipalities of the Toluca Valley shows that the largest number of agricultural tractors is over 15 years old, which exceeds the optimal for a useful life that is in accordance with the scientific and technical achievements of modern mechanization. In most of the municipalities studied, the amount of power per hectare is more than 2 hp ha⁻¹, a fairly high amount according to current standards, which require approximately 1 hp ha⁻¹.

The implement-tractor ratio is above 1, which is high, but contrasts with the number of hours used in agricultural work per year, which shows a non-full use of these tools in the agricultural cycle. The number of tractors with a 4 x 4 traction scheme is less than those with the 4 x 2 scheme or system, the former being more efficient in agricultural work. In the last five years there has been a significant fall in the purchase of tractors in these municipalities.

It is interesting to note that there is a preponderant tractor brand in the purchase by the owners and that they are not equipped with instruments (for example, GPS) that contribute to a greater optimization in the mechanized work of the field.

It is recommended to the government of the State of Mexico to establish a plan for the renewal of the park of tractors that have aged and that machines and tractors of an adequate power to the area that each farmer has are promoted, since they have tractors with a power above what is necessary, according to the area they have. The fundamental indices are below those recommended by FAO.

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