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TYPOLOGY OF MAIZE PRODUCERS IN TEPATITLÁN DE MORELOS, JALISCO, MEXICO

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ABSTRACT

Given the relevance of rainfed maize cultivation among farmers of the municipality of Tepatitlán de Morelos, a typification and characterization of the producers was conducted, with the purpose of generating useful information for decision making of the stakeholders involved in this agricultural activity. Four key components were identified through cluster and discriminant principal components analysis, with economic, sociodemographic and land area, and related to agricultural practices. The results allowed identifying three groups of producers with different levels of profitability, experience and technical skills, related to the final product, whether grain, fodder or stubble. In general terms, maize production in the study region is profitable. In addition, given the importance of livestock production in the zone, opportunities were identified to benefit both agricultural and livestock production activities. To increase the sustainability and profitability of production units, it is fundamental to implement training strategies to address the specific needs of each group identified. This would allow optimizing the agricultural practices and making the most of the resources available in the region.

Keywords: profitability, rainfed maize, technological index.

INTRODUCTION

Maize (*Zea mays*) is the most important crop in Mexico, because of its significance in the food, economic and cultural spheres. In 2023, 6.9 million hectares of maize were sown in the 32 states of the Republic, reaching a production of 27.5 million tons, equivalent to 88.2% of the national grain production (SIAP, 2023; SADER, 2023). Among the main producing states, the ones that stand out are Sinaloa, Jalisco, Estado de México, Guanajuato and Michoacán (SADER, 2023).

Jalisco stands out in agriculture and livestock production activities thanks to its favorable agroclimatic conditions, positioning itself as one of the main maize producers in the country. In 2023, 556.5 thousand hectares of grain maize were planted, obtaining a production of 3.49 million tons. In addition, 205.8 thousand hectares of maize for green fodder were cultivated, with a production of 4.58 million tons (SIAP, 2023).

In 2022, Tepatitlán de Morelos was positioned as the second municipality of the state of Jalisco in grain maize production, with a planted area of 27,360 hectares and a production of 211.3 thousand tons of grain (SIAP, 2023). This municipality is part of the region known as Altos de Jalisco Sur, characterized by its important dairy farming and growth of poultry farming to produce egg for dish, which sustains the production of fodders and grains (Castañeda *et al.*, 2014; Rea and Medrano, 2020). The importance of maize farming in Tepatitlán de Morelos justifies the constant search and update of information to support decision making. This is essential to direct strategies that maintain or improve the productivity and competitiveness of the crop.

The diversity in the agricultural production systems emerges from the physical, socioeconomic and technical variations of the producers and their production units. These differences give specific characteristics and problems to each, complicating decision making and the application of agricultural policies in a uniform manner (Mahendra, 2012; Sikwela *et al.*, 2016). Therefore, it is essential to classify and typify the farmers and their production units based on these differences and relations, with the aim of grouping the ones with similar characteristics (Borja *et al.*, 2018).

Various studies have addressed the typification of maize producers, highlighting different areas of interest. For example, Campos *et al*. (2022) focused on the search for information about the main practices used in maize production, while González *et al*. (2018) analyzed the productive factors that can strengthen production units. On the other hand, Martínez *et al*. (2020) contextualized the agroecological management with the objective of defining strategies of attention to producers in function of their daily practices. Likewise, Santos *et al*. (2014) used this approach to identify the characteristics and needs of the different types of producers and to propose elements of public policy.

In this context and considering the relevance of Tepatitlán de Morelos in maize production, the need to characterize producers and their production systems is identified, and to analyze the agronomic management that they carry out and the economic aspects related to this activity.

Derived from this, the objective was to conduct the typification and characterization of maize producers in the municipality of Tepatitlán de Morelos. This was done with the aim of generating information for decision making of the stakeholders that participate in the agricultural activity. The hypothesis suggested posits that maize production systems in Tepatitlán de Morelos, Jalisco, are significantly differentiated by productive, economic and social factors. These factors influence the cultivation practices and the productive dynamics of the region, which generates variability in the needs for crop management between the different producers. Therefore, it is imperative to define those needs in a differentiated manner and to develop training schemes and adapted strategies, directed at the specific characteristics of each type of producer.

THEORETICAL FRAMEWORK

In Mexico, maize is a strategic crop of great national relevance within the design of sectorial public policies. Therefore, it is essential to recognize the heterogeneity present in the production systems. In this context, the typification of becomes a key tool to optimize the allocation of public resources and to propose strategies that favor agricultural development (Tubalov, 2022; Yao and Wu, 2022). In addition, this typification allows a better understanding of the production process and facilitates the identification of areas of opportunity, aimed at improving the productivity and sustainability of the crop. It also contributes to the design of strategies for the transference of technology, training, management of productive projects, and allotment of economic resources in rural areas.

The construction of typologies is defined as the classification process of a set of units (individuals, institutions, societies, among others), into reduced and significant groups or categories, which share similarities with one another (López, 1996). In the case of the typologies of agricultural producers, the specific characteristics of farmers are considered, where each type represents a model that synthesizes a portion of the population studied. This gives place to sets of elements that share common conditions, whether individual or combined (Aguilar, 2016). According to Santos *et al*. (2014), the construction of a typology requires addressing the production units in a systemic manner, considering the diversity of characteristics and grouping the producers according to their predominant features. Therefore, the classification should consider variables related with the management, the production, and economic and social aspects.

The study is based on the Positivist Paradigm, which posits that reality is objective, measurable and susceptible to analysis through scientific methods. In this framework, two complementary theories were applied: the Theory of Human Capital, and the Theory of Agricultural Systems. The Theory of Human Capital maintains that the skills, knowledge and experiences acquired by individuals through education, training and practice have a direct impact on their productivity and the economic decisions that they make (Gómez and Tacuba, 2017; Herrendorf and Schoellman, 2018). According to Quintero (2020), the central idea of this theory is to consider the process of acquiring skills and knowledge as an investment, which not only increases individual productivity, but also sets the technical bases for economic growth. This approach allows identifying how technical capacities and soft skills, such as leadership, teamwork, and problem resolution, influence the organization and performance of agricultural producers. However, in agreement with what was exposed by Wuttaphan (2017), the Theory of Human Capital cannot operate in an isolated way; it must be integrated with other theories, such as systems, psychology, and various economic theories like that of scarce resources and sustainable resources.

On the other hand, the Theory of Agricultural Systems is a multidisciplinary approach that seeks to understand and analyze the interaction between the different components which make up an agricultural system. The study of agricultural systems implies analyzing their components and interactions, considering agricultural production, natural resources and the human factor (Jones *et al*., 2017). The systemic approach considers that each producer operates under a productive logic that depends on factors such as the availability of labor, land and capital. In addition, it highlights the importance of understanding local socioeconomic dynamics, before implementing technical changes or innovations.

An example of research conducted about typologies of producers developed under these theories is the study by Sinha *et al*. (2022), who considered social, personal, biophysical and technical characteristics to generate knowledge about the operationalization of typologies of agricultural households, with the aim of orienting the intervention of extension work among small-scale producers. Likewise, in the study by Innazent *et al*. (2022), agricultural systems were characterized with an approach in marginal agricultural households using typology, limitations were identified according to the types of agricultural exploitation, and interventions were proposed that were profitable and socially acceptable to overcome these limitations.

In conclusion, the integration of the Theory of Human Capital and the Theory of Agricultural Systems in the elaboration of typologies of farmers is fundamental for the integral understanding of the factors that influence the productivity and sustainability of agricultural systems. The Theory of Human Capital allows identifying how the capacities and skills of producers affect their decisions and performance. Meanwhile, the Theory of Agricultural Systems provides a systemic approach that considers the interactions between resources available, socioeconomic dynamics, and agricultural practices. Together, these theories offer a solid basis to develop more effective and contextualized interventions, which promote sustainable agricultural development and improve the conditions of producers.

METHODOLOGY

Study area

The study was carried out in the municipality of Tepatitlán de Morelos, Jalisco, located at parallels 20°35′ and 21°03′ of Latitude North, meridians 102°28′ and 102°57′ of Longitude West, and at altitudes ranging from 1,300 and 2,600 meters above sea level (Figure 1). This municipality is part of the region known as Altos Sur and has a temperate sub-humid climate with a temperature range of 16 to 22 °C and precipitation of 700 to 1100 mm (INEGI, 2010; Castañeda *et al.,* 2014).

Estimation of the sample size

To gather data, a survey was applied to maize producers, for which a representative sample was determined using the finite population method, based on information from the census of maize producers who are recipients of the "Producción para el Bienestar" program 2021, according to the following formula (Borja *et al.,* 2018; Téllez-Delgado *et al.,* 2012):

$$n = \frac{NZ^2 pq}{e^2\left(N-1\right)+Z^2 pg}$$

where n is the sample size; N is the population corresponding to the number of producers registered in the census (714); Z is the value of the standard

Source: prepared by the authors.

Figure 1. Location of the municipality of Tepatitlán de Morelos, Jalisco.

normal distribution for a level of confidence of 95% (1.96); *p* is the value of the proportion a priori of the maximum variance of a proportion variable (0.5); *e* is the maximum admissible error of the estimation, in this case 0.11 (11%). The estimated sample size was 67 producers.

Design and format of the survey

The questionnaire included closed and open-ended questions, and it was previously validated. The questions were related to the following themes: a) general data of the producers; b) corn production system; c) production costs; and d) producers' income. The surveys were applied in the months of May to August 2023, and producers were asked about the agricultural practices used during 2022. The selection of the producers surveyed was carried out based on their willingness and acceptance to answer the survey.

Information analysis

With the information obtained, a database was constructed with 40 original variables. To select the representative ones, the procedure suggested by Berdegué *et al*. (1990) was followed: first, the coefficient of variation (CV) was calculated for each, and those that had low discriminatory power (CV lower than 50%) were eliminated. Then, the degree of association between them was determined through a correlation matrix. In this way, the variables with high percentage of superfluous or highly correlated information were identified. Only one of the highly correlated variables was selected, which would be representative. In the end, nine original variables were considered (Table 1).
A synthetic variable called "technological index" (TI) was also estimated, which fulfilled the characteristics of being independent and relevant in the structure and functioning of the maize production systems. The TI was calculated considering factors such as the adoption of advanced technologies, agricultural innovations, infrastructure, equipment, education and training, among others; which can be used to increase productivity, improve sustainability, reduce

Table 1. Variables used in multivariate analysis**.**

Variable	Name	Variable	Name
X_1	Age	X_6	Maize yield
X_2	Years of study	X_7	Mean cost
X_3	Arable surface	X_8	Profitability
X_4	Surface sown with maize	X_9	Final product
X_5	Years of experience	X_{10}	Technological index

Source: prepared by authors.

costs, and promote competitiveness (Shi *et al.*, 2023; Zhang and Yang, 2021). The maximum value of TI was 10 and made it possible to determine the level of implementation of practices in the management of the corn crop. The variables mentioned in Table 2 were used for the index's estimation, with an arbitrary weighting factor.

To stratify the producers, factorial principal components analysis (PCA), hierarchical and K-means cluster analysis (CA), and discriminant analysis (DA) were used. In the PCA, the varimax rotation was used, with which the initial variables were reduced to factors that explained the higher variance in the global analysis. The hierarchical CA was used to identify the number of groups or producers graphically (dendrogram), based on Ward's algorithm. Subsequently, the analysis was complemented with the K-means for a better identification of the groups.

To test and validate the results obtained in the K-means CA, the classification and assignment of each individual to the group formed with a DA was evaluated (Díaz de Rada, 1998; Borja *et al.*, 2018). In the DA, the independent variables that most discriminate the groups were determined, and it was verified that the conformation of groups from the CA was robust. In the DA, the stepwise variable selection method was used. To select the variables, Wilk's lambda statistics were used, considering that if its value is close to zero, the total variability will be due to the differences between groups, and if its value is close to one, the groups will be mixed and the set of independent variables will not be adequate to build the discriminant functions (Ferrán-Aranaz, 2001; Vivanco *et al.*, 2010). The statistical analysis of the data was conducted with the SPSS 27.0 software for Windows (IBM, 2022).

Table 2. Variables considered in the estimation of the technological index in maize production.

Technological index	Technological component
Type of seed	Hybrid (2) Creole (1)
Organic fertilization	Biofertilizer (0.5); compost (0.5); leaches (0.5); bovine fertilizer (0.5)
Chemical fertilization	Ammonium sulfate (0.4); urea (0.4); simple calcium superphosphate (0.4); microelements (0.4); recommended dose (18-46-00) (0.4)
Herbicide	Pre-emergent (0.5); post-emergent (0.5)
Pest control	Worm traps (0.5); attractants (0.5); use of insecticides (1)
Disease control	Use of fungicides (1)

Source: prepared by the authors.

RESULTS

The feasibility of the principal components analysis was determined based on the following results. In the Kaiser-Meyer-Olkin (KMO) test, a value of 0.645 was obtained, and in Bartlett's test of sphericity, the F showed a significance of 0.000. The principal components analysis resulted in four factors that explained 74.7% of the total variance.

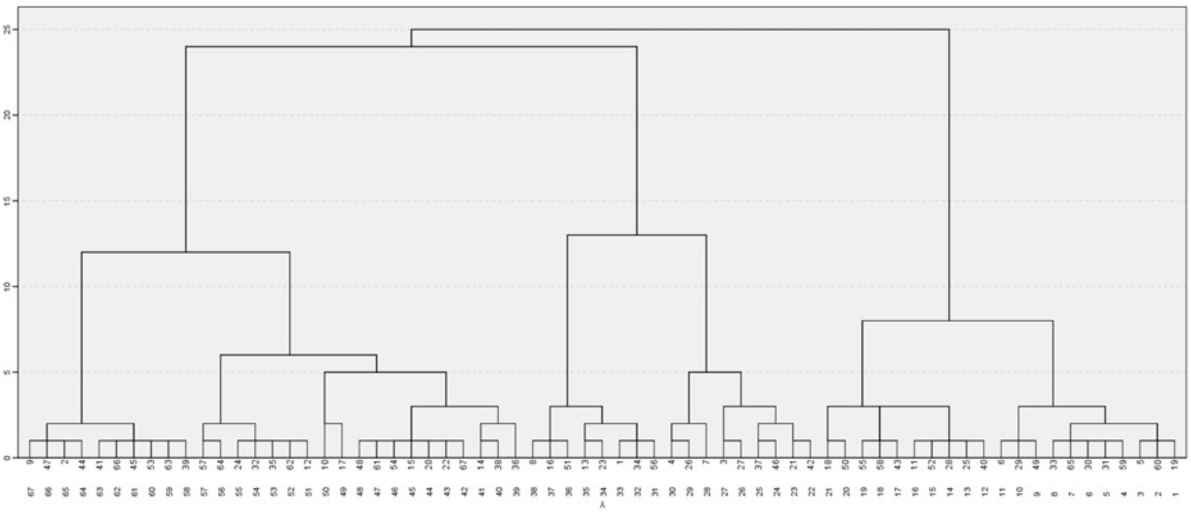
The first component was made up by the economic variables and called "crop profitability". The second component was integrated with the sociodemographic variables of the producers such as age, years of experience in maize production, and years of schooling, and it was called "productive capacities and skills". The third component was related to the area owned by the producer and the area sown with maize, called "size of the production unit". Finally, the fourth component was integrated by the type of final product, which could be: grain, forage or stubble. The last component was the TI, which represents the practices and activities that the producer carries out in the crop, designated as "agronomic management" (Table 3).

Using cluster analysis (CA) with the hierarchical method, three groups were identified (Figure 2). This information was considered to carry out the typification of the maize producers through the K-means method, where the producers were classified into three groups. The goodness of the classification was proven and it was determined that 100% of the survey respondents were classified in a correct and valid way. The interpretation of Wilks' lambda statistical value was 0.104, a value close to zero, which indicates that the groups formed were statistically different. According to this value and the F statistics, the four factors considered in the classification contributed to the discrimination of with a significance level of $p < 0.05$ and an F value greater than 3.84.

Table 3. Correlation between original variables and principal components.

Variable	Principal Component			
	1	2	3	4
Mean cost	-0.905			
Maize yield	0.843			
Profitability	0.815			
Years of experience		0.915		
Age		0.904		
Years of study		-0.520		
Arable surface			0.902	
Surface sown with maize			0.833	
Technological index				0.880
Type of product				-0.766

Source: prepared by the authors with survey data, 2022.



Source: prepared by the authors with survey data, 2022.
Figure 2. Dendogram of the types of maize producers in Tepatitlán, Jalisco.

Group 1: Small-scale producers

This group comprises 40% of the sample. The producers have an average age of 76 years, low educational levels, and the greatest experience in maize production. On average, they cultivate six hectares, dedicating 66.6% of the land to maize (Table 4). The final products are stubble and fodder. This group has the highest average production costs and the lowest TI, although they are considered profitable. All the members of this group (100%) receive government support.

Group 2: Medium-scale producers

This group was made up by 36% of the producers surveyed. The average age is 54 years and they are the youngest group. They have experience in maize production, but low educational level. Their average production unit size is nine hectares, with 77.8% destined mainly to maize cultivation for grain. The TI is similar to that of large-scale producers. In this group, 80% of the farmers receive government support, which complements their family income.

Group 3: Large-scale producers

Large-scale producers represent 24% of the survey respondents. They are characterized by being farmers with high experience in maize production, an average age of 62 years and low educational level. They mainly produce maize for grain and green fodder, products that allow them to be profitable (Table 4).

Table 4. Factors and variables that characterize maize producers.

Factor	Variable	Maize producers		
		Small	Medium	Large
1. Profitability of the crop	Average production cost ($ t^{-1})			
	Grain	5,006	4,716	4,129
	Fodder	1,184	532	477
	Stubble	3,137	2,766	3,685
	Maize yield (t ha^{-1})			
	Grain	8.9	9.3	9.6
	Fodder	65	73.3	66.6
	Stubble	13	16	10.3
	Profitability			
	Grain	1.6	1.6	1.7
	Fodder	2.3	2.1	2.8
	Stubble	1.8	2.3	1.3
2. Productive capacities and skills	Years of experience	60 ± 2.7	32 ± 3.0	43 ± 3.8
	Age (years)	76 ± 1.8	54 ± 2.0	62 ± 3.2
	Years of study	3 ± 0.3	5 ± 0.8	5 ± 0.37
3. Size of production unit	Arable surface (ha)	6 ± 0.9	9 ± 1.1	23 ± 3.6
	Surface sown with maize (ha)	4 ± 0.6	7 ± 0.8	13 ± 1.38
4. Agronomic management	Technological index			
	Grain	4.1	4.7	4.8
	Forage	3.8	4.0	4.1
	Stubble	3.5	3.7	3.6
	Type of product (%)			
	Grain	22.2	58.3	43.8
	Fodder	29.6	25	37.5
	Stubble	48.2	16.7	18.8
	Receive government support (%)	100	80	94

Source: prepared by the authors with survey data, 2022.

They have the largest arable surface and sow it with maize. They carry out low agronomic management, for fodder production; however, they increase the number of practices for grain maize production. A total of 94% of producers in this group receive government support.

DISCUSSION

The results show that maize cultivation is profitable for the three types of producers. The percentage of profit varies according to the final product and the market to which it is destined to. According to the data obtained, 40.1% of the survey respondents are devoted to grain maize production, 29.9% to green fodder, and the rest to stubble. In terms of product distribution by type of producer, the small-scale producers were concentrated mainly in the production of stubble, while the medium-scale producers were focused more on grain production, and the large-scale producers diversify their production, focusing their efforts on both grain and forage (Table 4). This pattern is closely related to the capacity for investment and the adoption of appropriate technologies, which highlights the importance of considering the economic and productive characteristics of each type of producer, as emphasized by the Theory of Agricultural Systems.

In the study region, 91% of the producers use improved seed and the rest creole varieties, mainly yellow maize. The productive yields are good, compared to those from other producing areas. The yield of rainfed maize grain ranged between 6 and 13 t ha^{-1}, while at the national level, it was within a range of 0.5 to 6.66 t ha^{-1} and at the state level, it varied from 0.85 to 8.7 t ha^{-1} (SIAP, 2023). Authors such as Castañeda *et al.* (2014) point out that the high yields are largely derived from the use of quality improved seeds adapted to local conditions. This allows the producers to increase the potential yield by up to 50%; however, the use of improved seeds causes an increase in the production costs of up to 20%. For their part, Ayvar-Serna *et al.* (2020) point out that success of the crop depends not only on the quality and quantity of the seed planted, but also on the type of soil, climate and management of the crop, from sowing to harvesting.

Large-scale producers showed the lowest costs in production means in maize for grain and fodder. In this regard, Ayala *et al.* (2014) point out that a lower cost per ton has a positive impact on the unitary profit, which is associated with better productivity, since more is produced with less investment. Consequently, large-scale farmers were the most productive in grain and forage, while small-scale producers were the least productive. In this regard, González-Pérez and Uriega-Chirino (2021) comment that, even though the climate conditions of the region may favor maize cultivation and represent an advantage, farmers produce with high input costs and have to compete with transnational companies. This analysis denotes the need to implement productive strategies that involve the use of new technologies, to decrease the production costs and increase the productivity and sustainability of the farming plots (Damián, 2023).

The productive capacities and skills of the farmers are correlated with age, education and years of experience in the economic activity. The importance of analyzing these traits of producers is related to the introduction and use of technological innovations in the production units (De Freitas and Pinheiro, 2013). School education provides producers with tools to seek better business opportunities, facilitates access to information and state instruments (programs, support, subsidies, among others), and allows them to connect with local networks, agroindustry and various markets (Fawaz, 2007).

Concerning age, the three types of farmers were on average, over than 50 years old. This is consistent with the findings by Tucuch-Cauich *et al.* (2007) and Uzcanga *et al.* (2015) in Campeche, de González *et al.* (2018) and Arias-Yero *et al.* (2022) in Chiapas, de Baltazar *et al.* (2011) in Aguascalientes, and Jaramillo *et al.* (2018) in Veracruz, who showed that the ages of maize producers fluctuated around 50 years old.

The studies mentioned in the previous paragraph also reported that among maize producers, an educational level of primary school predominates and there is a high degree of illiteracy. According to INEGI (2023), in 2020, the state of Jalisco had an average educational level of 8.7 years, equivalent to secondary school, while the average of the surveyed producers was four years, lower than the state average.

The maize producers from Tepatitlán de Morelos show broad experience in the production of this crop. In their majority, they have been devoted to this economic activity for more than 30 years, which marks an important productive tradition among farmers. However, given the aforementioned characteristics, there has not been a generational renewal of producers in the region, which is of utmost importance. According to Tucuch-Cauich *et al.* (2007), the processes of technology adoption can be facilitated to the extent that young people take on a leading role in maize production.

None of the three groups of producers showed important differences in the TI for forage maize and stubble. However, in grain production, differences were observed mainly between the medium-scale and large-scale groups compared with the small-scale ones. The main differences in grain maize production between the groups were associated with the frequency of use of biological inputs such as manure, weed control, and pest and disease management in the crop. This agrees with what was reported in the study by Castañeda *et al.* (2014), who mentioned that the small-scale and medium-scale maize producers in Jalisco have similar production conditions, such as machinery, chemical inputs and hybrid seed.

Even when the use of organic fertilizers was observed in medium-scale and large-scale producers, only 32.8% of the survey respondents use this type of inputs in their production system. The implementation of the use of bioinputs can be an alternative to improve the productivity and competitiveness in grain production. As has been shown in other studies, the combination of chemical and biological fertilization tends to increase the yield both of grain and of green and dry forage (Ayvar-Serna *et al.,* 2020), in addition to contributing to improving soil and increasing the profitability of the crop (Mancilla *et al.,* 2020). The adoption of organic inputs in production systems can be an effective and economical alternative for producers. In Tepatitlán de Morelos, the livestock activities, mainly poultry, pork and cattle production (Rea and Medrano, 2020; Unger, 2023) are of great importance, which would allow taking advantage of manures as input in agricultural activities.

The classification carried out allows discerning the importance of defining technological packages to increase the productivity considering into consideration the final product (grain, forage and stubble). Through the application of technological packages, the economic optimization of inputs must be sought, to reduce the production costs, which represents one of the main challenges for producers (Castañeda *et al.,* 2014).

In summary, the results of the study show that the factors associated with human capital, such as age, education and experience, are related to productive decisions and the adoption of technologies. The Theory of Agricultural Systems also highlights the interaction between the various components of the production system, where the available resources, technical capacities and management practices have a direct impact on the profitability and sustainability of farms. To improve the competitiveness and sustainability of the producers, it is essential to implement differentiated strategies that consider the particular characteristics of each type of producer and foster the adoption of more sustainable and efficient technologies, such as using organic inputs and improving technical training.

CONCLUSIONS

The typification of rainfed maize producers, according to economic, sociodemographic and productive variables, allowed the identification of three differentiated groups: small-scale, medium-scale and large-scale producers. Maize cultivation is profitable for the three types of producers identified. However, profitability varies according to the final product (grain, forage, stubble), and the market to which it is destinated. The large-scale producers showed the lowest average production costs, which allows them to be the most productive and profitable. The adoption of improved technologies, such as the use of quality seeds and the combination of chemical and biological fertilization, has proven to be effective in increasing maize yield. However, the incorporation of organic inputs, such as manures derived from the local livestock activities, can be an economical and effective alternative to improve the productivity and sustainability of the maize cultivation.

This classification provides relevant information, both for the definition of technological packages and for the development of specific policies and strategies adapted to the needs of each group, thus optimizing the allotment of resources and the effectiveness of government interventions. There is an urgent need to implement differentiated training programs for each type of producer, to strengthen the productivity and sustainability by using new techniques.

Among the main challenges for producers is the optimal use of inputs to reduce production costs. In addition, the lack of generational renewal in maize production and the low schooling of producers limit the adoption of new technologies. Encouraging the participation of young people in agricultural production and improving the educational level of producers are fundamental strategies to ensure the future of maize production in the region.

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