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Article

Rural sustainability: corn production and profitability in Ayotzintepec

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Abstract

Corn in Mexico is a central component of the economic and productive structure and of the nutritional value of the diet of rural communities, where its efficient management determines the viability of sustainable agricultural systems. This research aimed to analyze the profitability of corn production in the peasant locality of Ayotzintepec, Oaxaca, for the autumn-winter cycle (2023-2024); to this end, production, population characteristics, and economic variables, including production costs, profits and the benefit-cost ratio, were estimated. In the study, significant differences were found in the economic variables and in the three types of ejidatarios (shareholders of common land): Mixed: ejidatarios with owned and leased land (29.49%); owned land: ejidatarios only with owned land (64.1%); tenant: ejidatarios with leased land, (6.41%); these ejidatarios were identified in five categories according to yield: category I) yield ≥4 #5 t ha^{-1}; category II) ≥5.1 ≤6 t ha^{-1}; category III) ≥6.1 ≤7 t ha^{-1}; category IV: ≥7.1 ≤8 t ha^{-1}; and category V) ≥8.1 t ha^{-1}. The economic evaluation indicator, the benefit-cost ratio (B/C), for the three groups in the five categories was: Mixed) 1.34 MXN, owned land) 1.72 MXN; and tenant) 1.4 MXN. The results showed that corn production is strategic for the basic diet and food sovereignty of the population of Ayotzintepec, Oaxaca.

Keywords:

agricultural system, cultural territoriality, food sovereignty, planting.

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Introduction

Corn production is a fundamental part of Mexico's history and identity (Gobierno de México, 2024). In 2023, 6.3 million hectares of corn were planted, with a production of close to 29.4 million tons and an average yield of 3.95 t ha^{-1} (SIAP, 2023); although Mexico is self-sufficient in white corn, in yellow corn, it only satisfies 11.6% of the national demand (SIAP, 2024; FIRA, 2024).

In Oaxaca, the annual demand is 771 500 t per year (t year^{-1}), and the average production is 566 000 t year^{-1}, generating a deficit of 205 500 t year^{-1}, mentioning that planting is carried out in two cycles: spring-summer and autumn-winter (SEGEGO, 2017). The most important regions for corn cultivation are: Istmo, Mixteca, Central Valleys, and Coast. However, the Papaloapan Basin stands out for its potential, with yields of 5.49 t ha^{-1} in Ayotzintepec, compared to the state average of 1.35 t ha^{-1} (Armendáriz *et al*., 2024; Rodríguez *et al*., 2024).

Materials and methods

The research was carried out on a population of 97 farmers from Ayotzintepec, listed in the registry and history of agrarian nuclei (Phina, 2017). The sampling method was completely random; for the analysis, descriptive and inferential research methods were used. The inquiry to collect the farmers' data included: how much do they produce? And for whom do they produce? The sample was obtained with a 95% confidence level and a 5% margin of error, yielding a total of 78 farmers.

Profitability estimation

The study was conducted during the 2023-2024 autumn-winter cycle, calculating the crop's total production cost and income. The costs were divided into direct (inputs, machinery, labor) and indirect (semi-annual land rent, considering two agricultural cycles per year). To estimate profitability and yield per hectare in the autumn-winter cycle, the costs of inputs and production activities were considered based on the average prices recorded in 2023 in Ayotzintepec.

The analysis was based on the economic model proposed by Samuelson and Nordhaus (2009), which allows us to formalize cost and revenue calculations through algebraic expressions. Where: total cost (TC) is defined as the minimum monetary expenditure necessary to obtain a level of production and is expressed as follows: TC= Px. TC= total cost of production; P = price of input or activity X; and X= activity or input.

The total income per hectare is obtained by multiplying the yield of the crop by its market price. The algebraic expression is: TI=Py; TI= total income ($ ha^{-1}); Py= market price of product Y ($ t^{-1}); Y= crop yield (t ha^{-1}). Profitability is finally equal to: profitability= TI-C; TI= total income ($ ha^{-1}); TC= total cost of production; benefit-cost= I, which results from subtracting total cost from total income.

Results and discussion

Characteristics of farmers

Ninety-one percent of producers are men and 9% are women, with an average age of 49 years (range from 24 to 79), and families are composed of four members. Ninety-one percent of the population is bilingual, speaking Spanish and an indigenous language, whereas 9% only speak Spanish. This data contrasts with the state and national trends, where the indigenous language has been declining; in Oaxaca, only 27.3% of the population speaks an indigenous language, and at the national level, only 5.9% of the population over three years old does so (INEGI, 2024). This suggests a progressive loss of cultural ties and identity.

In terms of labor, 97.4% of producers work their own land only, and 2.6% work occasionally for others, with an average daily wage of $182.00 MXN; in addition, all of them mentioned having basic services: water, electricity, and drainage. As for complementary income, 19% receive average monthly remittances of $2 900.00 MXN, and 55% access the Proagro program with an amount

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similar to $778.00 MXN, which continues to arrive with delays, which limits the ability of farmers to maintain corn planting and contribute to the reduction of the national deficit (SADER, 2024; Gobierno de Oaxaca, 2024).

In addition, official statistics show that, in Oaxaca, corn producers receive technical training and access to technological packages and fertilizers; nevertheless, they continue to demand greater efficiency and timeliness in the delivery of support. This delay in the application of resources directly affects the motivation to invest in agricultural production and thus slows down the possibility of reducing dependence on imports, especially in this type of locality, where corn, beyond its agro-productive function, represents an economic and sociocultural axis. This reflects the fact that 88% of its inhabitants historically identify with the indigenous language (INEGI, 2024), and the cultivation of corn continues to be an essential part of the community fabric; however, demographic, linguistic, and institutional support changes indicate the tensions between the persistence of traditional practices and the structural transformations of the rural environment in Mexico.

Production characteristics

Farmers planted an average of 6.04 ha with a planting density of 61 400 seeds ha^{-1} in the autumn-winter cycle. In the community of Ayotzintepec, 100% of farmers are mainly engaged in corn cultivation; of these, 9.36% grow other crops, such as beans and chili, and engage in livestock farming. Of the 78 farmers surveyed, 94% sow white corn and 6% yellow corn. In the 2023-2024 autumn-winter cycle, the average yield was 6.9 t ha^{-1}, higher than that reported by Rodríguez *et al*. (2024), which was 5.29 t ha^{-1} on average in the municipality of Ayotzintepec and 2.7 t ha^{-1} in the locality.

In the production process, it was found that 100% of farmers use improved seed, mainly hybrids from commercial houses: Pioneer with 61.5%, Reycoll with 28%, Dekalb with 9%, and Sorento with 1%.

Types of farmers

In the study, three types of farmers were identified, as described in Table 1, which lists the types of farmers in the first column and the percentages in the last. Tenant ejidatarios (TEs): this first group produces on leased land, and only represents 6.41% of the population; mixed ejidatarios (MEs): these are farmers who produce on their own and leased land, representing 29.49% of the total; and ejidatarios with owned land (EOs): they are farmers who produce only on land they own and represent the highest percentage, with 64.1%.

Table 1. Yield categories by type of farmers in the locality of Ayotzintepec, Oaxaca.

Type of ejidatario	Categories	Yield (t ha^{-1})	Num. of farmers	(%)
TEs	I	≥4 to ≤ 5	0	0
	II	≥5.1 to ≤6	3	3.85
	III	≥6.1 to ≤7	1	1.28
	IV	≥7.1 to ≤8	1	1.28
	V	≥8	0	0
MEs	I	≥4 to ≤5	1	1.28
	II	≥5.1 to ≤6	7	8.97
	III	≥6.1 to ≤7	9	11.54
	IV	≥7.1 to ≤8	6	7.69
	V	≥8	0	0
EOs	I	≥4 to ≤5	1	1.28

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Type of ejidatario	Categories	Yield (t ha^{-1})	Num. of farmers	(%)
	II	≥5.1 to ≤6	8	10.26
	III	≥6.1 to ≤7	24	30.77
	IV	≥7.1 to ≤8	16	20.51
	V	≥8	1	1.28

TEs= tenant ejidatarios; MEs= mixed ejidatarios; EOs= ejidatarios with owned land.

Although most work on their own land, almost 36% depend wholly or partially on leasing, reflecting a well-founded and vulnerable agrarian structure. This trend coincides with estimates by ASERCA (2021), which indicate that 40% of agricultural land is leased; nevertheless, the actual figure could be higher, as some producers lease land only to access subsidies such as Proagro, which limits investment and long-term sustainability (CIMMYT, 2023). In addition, according to González-Estrada (1999), about 66.2% of the corn agricultural area is under some form of lease, reflecting a growing pressure on peasant tenure.

In this sense, the high proportion of producers with owned land is positive, but the significant presence of leasing schemes reveals structural challenges that impact food security and rural autonomy. This is because land tenure directly determines producers' investment capacity, productive planning and economic stability. Farmers who work on leased land often face greater risks, as they rely on temporary contracts and are less incentivized to make long-term investments. As a result, widespread leasing limits the sector's sustainability and productivity, creates structural vulnerability and conditions local and regional food security.

Analysis of the profitability of corn production of the three types of ejidatarios (TEs, MEs and EOs)

Analyzing the three types of ejidatarios, it was found that tenant ejidatarios (TEs) are the ones with the highest average total cost per hectare with $19 962.14 MXN; in second place are the mixed ejidatarios (MEs) with $18 247.41 MXN and finally the ejidatarios with owned land (EOs) with $14 581.18 MXN ha^{-1}.

In relation to the profit per hectare ($ ha^{-1}), the EOs showed the highest value with $10 714.37 MXN, followed by the TEs with $6 597.85 MXN per hectare and the MEs with $6 264.98 MXN per hectare. Nonetheless, analyzing profit per planted area ($ area^{-1}), it was found that the ejidatarios who obtained the highest profit are the MEs, with an average of $69 834.98 MXN, a difference of $11 233.12 MXN compared to the EOs and $47 289.68 MXN compared to the TEs.

The reason why mixed ejidatarios obtain a higher profit per planted area is that the investment costs are distributed among the total number of hectares planted by the ejidatario; thus, it is assumed that the more the planted area, the greater the profits (Table 2).

Table 2. Total costs per hectare, profit per ha and profit per planted area of ejidatarios with owned land (EOs), tenant ejidatarios (TEs) and mixed ejidatarios (MEs). Autumn-winter agricultural cycle.

Type of ejidatario	Category I	Category II	Category III	Category IV	Category V	Average ($)
			Total cost (cost ha^{-1})			
TEs	-	20 134.00	19 688.25	20 064.18	-	19 962.14
MEs	16 186.68	18 242.58	19 154.24	19 406.16	-	18 247.41
EOs	11 943.99	14 382.87	15 316.97	15 096.87	16 165.20	14 581.18
			Profit ($ ha^{-1})			
TEs	-	2 566.00	7 261.75	9 965.81	-	6 597.85
MEs	3 063.31	4 921.19	6 997.24	10 078.21	-	6 264.98
EOs	5 606.08	7 574.94	10 608.15	13 772.87	16 009.80	10 714.37
			Profit per area planted ($ area^{-1})			

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Type of ejidatario	Category I	Category II	Category III	Category IV	Category V	Average ($)
TEs	-	5 987.33	21 785.25	39 863.24	-	22 545.27
MEs	22 974.82	36 515.22	80 468.26	139 381.64	-	69 834.98
EOs	11 212.16	34 560.66	61 438.87	89 738.85	96 058.80	58 601.86

With this, it is assumed that the ejidatarios that present the most costs are the TEs; on the other hand, the MEs are the ejidatarios that obtain the greatest profit per total planted area, whereas the EOs will be the ones that will obtain the highest profit per hectare; however, statistical analyses were performed to find statistically significant differences.

These results align with studies by CIMMYT (2023) and FAO (2021), which highlight the importance of land tenure and the size of the rented area; in addition, dependence on leasing limits investment and increases economic vulnerability (CONEVAL, 2020; ASERCA, 2021).

Aguilera's (2017) findings established that when the benefits outweigh the costs, the investment is profitable; this principle remains valid in the current analysis of corn production, in which recent studies confirm that producers with the highest yields per hectare obtain the best benefit-cost ratios (B/C> 1.38), especially in conventional systems that achieve ratios of up to 1.38-1.5 (Carrillo-Martínez *et al*., 2019).

Nevertheless, it has been observed that small-scale categories (I and II) continue to receive lower relative benefits, underscoring the need to focus resources on increasing yields per hectare through efficient inputs and technical advice (Guera, 2025). These findings reinforce the hypothesis of Ramírez and Peña (1985); Ayala-Garay *et al*. (2013), which directly relates profitability to high yields per unit area.

Statistical analysis

Three variables were analyzed: cost per hectare, profit per hectare and benefit-cost ratio, in MEs and EOs. TEs were ruled out in categories I and V because the number of these farmers did not meet the condition of minimum samples for the comparison of means, as is the case with MEs in category V (Table 3).

Table 3. Mean square error for ejidatarios with owned land (EOs) and mixed ejidatarios (MEs) in the variables cost, profit, and benefit-cost ratio per ha.

Source of variation	Cost	Profit	Benefit-cost
Ejidatario ($)	123696103.5**	76446606.4**	0.83113611**
Category ($)	4244337.5NS	92922455.6**	0.26300278**
Ejidatario by category	842303.9NS	6319428.9NS	0.06103611NS
Error	0.46867	0.682412	0.61724
Mean ($)	16 491.54	9 434.738	1.6

NS= not significant; *= significant $p \leq 0.05$; **= highly significant $p \leq 0.01$.

The average cost per hectare was $16 491.54 MXN ha^{-1}. Significant differences were identified between types of farmers (p = 0.001), but not between categories (p = 0.442), nor in the farmer-category interaction (p = 0.8474). This indicates that EOs and MEs differ in costs, but do not depend on the productive category, suggesting structural differences in the management and use of resources (FAO, 2021; SAGARPA, 2024).

As for the profit per hectare, it averaged $9 434.73 MXN ha^{-1}. Significant differences were found both between types of farmers (p = 0.0002) and between categories (p = 0.0001), but not in their interaction (p = 0.2434). This suggests that profits per ha depend on the tenure regime and the level of productive management, but not on a combination of both studies. Data from CIMMYT (2023) confirm that producers with owned land tend to have higher margins due to better control of inputs and less financial pressure.

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On the other hand, the average benefit-cost ratio was 1.6, which means a net profit of $0.60 per peso invested. Significant differences were detected between types of farmers (p = 0.0001) and categories (p = 0.0011), but not in their interaction, reinforcing the idea that profitability varies by producer type, beyond their production level.

Therefore, these results show that the type of land tenure (own or mixed) significantly influences costs, profits and profitability independently of the productive category. This highlights the need for differentiated policies according to the agrarian regime that consider access to land as a determining factor in productive efficiency (CONEVAL, 2020; FAO, 2021; ASERCA, 2021).

Table 4 presents the minimum significant difference (HSD) test between mixed farmers (MEs) and farmers with owned land (EOs), comparing three key variables: variable cost, profit per hectare and benefit-cost ratio.

Table 4. Difference between mixed ejidatarios (MEs) and ejidatarios with owned land in variable cost, profit and benefit-cost ratio per hectare.

Ejidatario	Cost	Profit	Benefit-cost
MEs	18 345.2 a	7 977.5 b	1.45278 b
EOs	14 637.9 b	10 892 a	1.75667 a
HSD ($p \leq 0.05$)	2 263.7	2 078.5	0.176

Identical letters within columns indicate a significant difference between types of farmers.

Table 4 detected significant differences between the two types of ejidatarios, with the mixed ejidatarios (MEs) presenting the highest variable costs, which can be attributed to the need to lease land, pay additional labor, or face higher logistical expenses. The EOs achieved greater profit per hectare, reflecting greater economic efficiency by not assuming lease costs and possibly having more comprehensive management of their productive unit.

In terms of the benefit-cost ratio, EOs also outperformed MEs with a ratio of 1.76 *vs* 1.45, implying that, for every peso invested, EOs earn $0.76 cents compared to $0.45 for MEs. These findings are consistent with studies by CIMMYT (2023) and FAO (2021), which highlight how land tenure directly influences the profitability and sustainability of agricultural production. Farmers who own land have greater investment capacity, long-term planning, and economic resilience (SAGARPA, 2024). In addition, CONEVAL (2020) stressed that landless producers face greater economic vulnerability and dependence on subsidies, implying limited room for maneuver to improve yields and adopt sustainable practices.

Tukey's test between categories for the variables cost per hectare, profit per hectare and benefit-cost ratio

Table 5 shows the results of the Tukey test applied to categories II, III and IV to evaluate three variables: cost per hectare, profit per hectare and benefit-cost ratio.

Table 5. Tukey's test between categories for the variables cost per hectare, profit per hectare and benefit-cost ratio

Category	Cost	Profit	Benefit-cost
IV	17 176.4	11 973.6 a	1.72667 a
III	16 193.4	9 870.9 b	1.6475 a
II	16 104.9	6 459.7 b	1.44 b
HSD ($p \leq 0.05$)	2 263.7	2 078.5	0.176

Different letters within the same column indicate statistically significant differences between categories, according to the HSD test ($p \leq 0.05$). By contrast, values with the same letter do not differ statistically.

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Analyzing the cost-per-hectare results, no significant differences were detected among the three categories. This suggests that the level of investment per hectare remains relatively stable, regardless of management level or production scale. Regarding profit per hectare, there were significant differences; category IV was the most profitable with $11 973.60 MXN ha^{-1}, surpassing categories II and III.

The differences between category III and II were $3 411.20 MXN, which indicates that the higher the level of management and possibly the greater the technification, the better the profitability per area; this agrees with Ayala *et al*. (2023), where profitability was analyzed in three categories with a single type of producer, and it is assured that the most useful category is the one that produces the most. Regarding the benefit-cost ratio, the relative profitability was higher in categories IV (1.73) and III (1.65), with no significant differences between them; however, both were higher than category II (1.44). This implies that, although the costs are similar, the return on each peso invested is higher at the most advanced production levels.

These results indicate that profitability is linked not only to the level of investment but also to the efficient management of resources and possibly, to the use of better agricultural practices (Mercado and Yañez, 2023; Ouorou *et al*., 2025). FAO (2021); CIMMYT (2023) agree that technical knowledge, diversification, and access to technology are determining factors in corn productivity. In addition, SAGARPA (2024) highlights that the most profitable productive units tend to combine traditional practices with technological innovation, which aligns with what is observed in categories IV and III. For its part, CONEVAL (2020) warns that producers with lower profitability (such as those in category II) face greater economic risks due to a lack of access to technical assistance or financing.

Conclusions

Corn production is strategic for the base diet and food sovereignty in Ayotzintepec, Oaxaca. Additionally, the key to increasing productivity lies in decreasing costs per hectare; the higher the average yield, the lower the cost of production per tonne, directly impacting profits. Of the three types of ejidatarios found in the locality, all recover the investment and obtain profits.

The ejidatarios who obtain the highest cost-effectiveness according to the financial indicators, benefit-cost ratio and profit per hectare, are the ejidatarios with owned land (EOs), which results from not disbursing capital for the rent of land for the production of corn. In the region under study, as well as in the country, there is the production capacity and sufficiency to reduce the existing corn deficit and stop importing it if effective subsidies are provided to the countryside through programs that directly benefit producers.

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