v. 5, n. 6, 2025

Journal of Agricultural Sciences Research

Acceptance date: 29/07/2025
Submission date: 26/06/2025

CONTRIBUTION TO THE COFFEE ECONOMY OF THREE SELECTED MUNICIPALITIES IN THE LAXAXALPAN MIDDLE WATERSHED

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Abstract: In the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya, located in the middle zone of the Laxaxalpan watershed in the state of Puebla, cherry coffee (*Coffea arabica*) plantations are economically important, as they provide monetary resources to forest dwellers around three years after planting the coffee tree and with a productive life of around 25 years. These plantations require shade for greater production, which is why they complement the natural forests of the basin. Their contribution to the region's economy is significant, since in 2023, the value generated by coffee plantations was 66.9 million pesos at market or current prices, which came from a relatively small planted area of 2,543 hectares, from which 8,335 tons of cherry coffee were obtained, and the municipality of Tlapacoya contributed half of the production volume of the municipalities considered in the study. With the exception of average yield per hectare and production, which were both negative, production value, average yield per hectare, and average rural price showed positive rates.
Keywords: cherry coffee, average rural price, average yield per hectare, average annual growth rate, production value.

INTRODUCTION

The Laxaxalpan River Basin is a hydrological region located in the Sierra Norte of the State of Puebla, Mexico. It forms part of the Tecolutla River hydrographic system and covers an area of approximately 1,682 km² until it joins the Necaxa River. The Laxaxalpan River originates in the Peñón del Rosario hill, located in the state of Tlaxcala, at an altitude of 3,250 meters above sea level. Its course follows a northeastern direction, passing through mountainous areas and small valleys, and crosses towns such as Zacatlán and Chiconcuautla in Puebla (UACH 2007). Along its course, it receives contributions from several tributaries, including the Hueyapan, Tepeixco, Tlaxco, and Zempoala rivers, which contribute significantly to the flow of the Laxaxalpan River. The outstanding feature of the basin is its integration into the Necaxa Hydrological System through a series of intake works and tunnels that allow water to be diverted to the Nexapa reservoir. Through its infrastructure works, water is collected from around 40 streams in the Laxaxalpan River sub-basin, with a total flow of approximately 30 m^3/sec (SRH 1970).

The region faces various environmental challenges, including land use change. In addition, inappropriate land use affects water quality and local biodiversity. Extreme weather events, such as heavy rains, cause flooding in residential areas, highlighting the need for integrated watershed management.

Coffee farming in the Laxaxalpan Hydrological Basin is of great economic importance in Mexico, especially in rural highland and mid-mountain regions. Its relevance in the country lies in the following aspects: More than half a million coffee producers in Mexico depend on cherry coffee production as their main source of income, most of them small-scale producers from indigenous communities (≤ 2 hectares) in states such as Chiapas, Veracruz, Puebla, Oaxaca, and Guerrero. The process of growing, harvesting, manually picking, and pulping cherry coffee requires a large temporary and permanent workforce, which generates direct and indirect jobs.

Globally, Mexico ranks 13th with a contribution of just over 1 million tons and in terms of planted area, which means that it accounts for 5.3% of the world's total area, amounting to 12.2 million hectares. The state of Puebla occupies an important place in coffee production, ranking third with 22.3%, behind Chiapas and Veracruz, respectively. The five months with the highest coffee production are

from November to March. (SADER 2024).

Cherry coffee is the unprocessed fruit of the coffee tree (before being pulped to obtain the green bean), which is washed and pulped before being dried in the sun, bagged, and transported for sale.

METHODOLOGY

The methodological process used was divided into two phases:

I) Phase: Analysis of land use dynamics through analysis of INEGI land use and vegetation layers covering a 20-year period. With a spatial resolution of 6.25 hectares. This was carried out using a QGIS geographic information system.

II) Phase: A five-stage documentary phase:

First: selection of the topic to be studied. For the socioeconomic research, the topic chosen was the evolution of the area planted with cherry coffee plantations in three municipalities in the state of Puebla, located in the middle of the Laxaxalpan watershed, which were selected because they had statistical data available: Ahuacatlán, Amixtlán, and Tlapacoya (Figure 1).

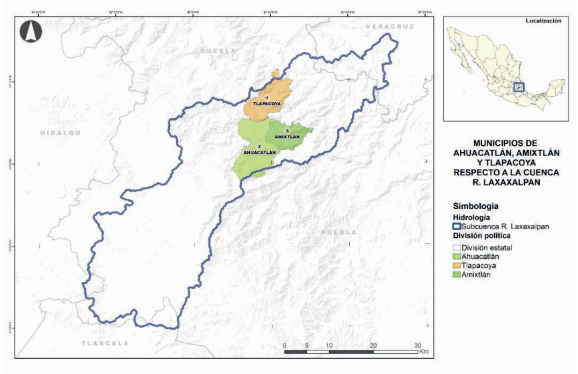

Figure 1. Selected municipalities in the Laxaxalpan basin

Second: collection of information from secondary documentary sources. The main idea was to compile statistics for the purpose of quantification, organization, and classification in order to assess the importance of the topic. This involved searching for and locating documents stored in information centers, libraries, reference centers, databases, and articles and summaries of national and international seminars and conferences, among other sources. During this phase, an Excel database was designed and developed, which was fed with information generated by the Agrifood and Fisheries Information System (SIAP) of the Ministry of Agriculture and Rural Development (SADER) in its various documents published periodically at , which were used to organize the documentary sequence. The study period was defined according to the national accounts published by the aforementioned source for the 21-year period (2003–2023), and the base year used was 2018 in order to use constant prices so that the data could be compared when analyzing the value of cherry coffee production.

Third: preparation of the research plan, in order to organize and exercise thinking and understanding, as well as to ensure that the concepts have a logical and systematic structure for prioritization. The indicators chosen were planted area (in hectares), average yield per hectare (in tons/ha), cherry coffee production (in tons), average rural price (in $/ton), and production value (in thousands of pesos). Data on the economically active population (men, women, employed, and unemployed) was also considered.

Fourth: organization of the information collected, which was done by indexing the content and secondary sources of information, segmenting them by the indicators mentioned in the previous point and visualizing the contribution of each of them to the local economy, allowing for a better understanding of the topic.

Fifth: selection of the statistical indicator. The mathematical formula that best reflects

annual growth was considered to be the average annual growth rate, as it is assumed to best reflect the growth of an activity in the medium and long term. Its mathematical expression is:

$$TMCA = ((Vf / Vi) \wedge (1 / n) - 1)) * 100.$$

Where Vf is the final value for the period; Vi is the initial value for the period; and n is the number of years considered in the analysis.

Similarly, the growth of a specific year was taken into account and compared with the previous year to facilitate and identify the sizes of positive and negative increases resulting throughout the period (Addin Technology, 2018). A trend line was also included to provide a better understanding of the evolution of the indicators.

RESULTS

The variables selected to visualize economic performance over the 21-year period covered by the analysis (project horizon) were: i) coffee planted area in hectares in each of the municipalities of the Laxaxalpan middle basin; ii) coffee harvested area in hectares; iii) coffee production in tons; iv) average coffee yield per hectare in tons per hectare, v) average rural coffee price in pesos per ton, and vi) value of coffee production in thousands of pesos; this variable was expressed in two ways, in current pesos and in constant prices.

Analysis of the area planted with cherry coffee shows that it has remained virtually unchanged throughout the period studied.

i) Coffee harvest area (hectares).

Table 1 shows data on the areas of coffee harvested during the period 2003–2023 in the three municipalities selected from the middle Laxaxalpan basin.

Table 1 shows that in 2010 there was a drop of almost half in the area harvested, followed by a significant recovery in the cherry coffee harvest the following year, but without reaching the level at the beginning of the period. Starting in 2013, there was a recovery in the planted area, slightly exceeding (52.4 hectares) the area at the beginning of the period. The sharp decline in the harvested area was mainly due to two factors: a drop in domestic and international prices for cherry coffee and the occurrence of extraordinary frosts.

Figure 2 shows the behavior and recovery of the cherry coffee harvest area in the municipalities of the Laxaxalpan middle watershed.

Figure 2 shows that the area harvested for cherry coffee in the middle of the basin between the start of the study (2003) and the end of the period (2023) remained largely unchanged. although in 2017 there was a sharp decline in the harvested area, which was most noticeable in the municipality of Tlapacoya. From 2018 onwards, a slight recovery was observed, until the initial area was reached. This can be explained by a polynomial equation:

$$y = 5.5083x^2 - 116.37x + 2726.2$$
$$R^2 = 0.3692$$

This indicates a low correlation in the trend due to the drastic drop in the area of coffee harvested. Similar to the planted area, the three municipalities under study represented only 3.83% of the total harvested area in the state of Puebla.

i) Average yield per hectare (ton/ha).

Table 2 shows the average yields per hectare obtained during the 21-year period analyzed (2003–2023) in the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya.

Table 2 highlights the municipality of Tlapacoya, which led in average yield per hectare of cherry coffee during the period

Year	Ahuacatlán	Amixtlán	Tlapacoya	Total	Increases (%) + or -
2003	412.65	814.75	1,263.00	2,490.40	-
2004	412.65	814.75	1,263.00	2,490.40	0
2005	412.65	814.75	1,263.00	2,490.40	0
2006	413.40	815.00	1,263.00	2,491.40	0.0420
2007	413.42	815.03	1,263.00	2,491.45	0.00
2008	412.65	814.75	1,269.00	2,496.40	0.1987
2009	412.65	814.75	1,269.00	2,496.40	0
2010	182.65	438.75	698.00	1,319.40	-47.1479
2011	412.65	814.75	698.00	1,925.40	**45.93**
2012	412.65	814.75	698.00	1,925.40	0
2013	412.65	814.75	698.00	1,925.40	0
2014	413.65	815.00	983.00	2,211.65	14.8670
2015	405.50	796.50	1,028.21	2,230.21	0.8392
2016	405.30	796.00	1,063.00	2,264.30	1.5264
2017	400.00	756.00	1,268.00	2,424.00	7.0530
2018	403.00	768	1,290.00	2,461.00	1.5264
2019	402.00	760	1,270.00	2,432.00	-1.1784
2020	400	766	1,274.0	2,440.00	0.3289
2021	412.00	788	1,312.00	2,512.00	2,950.8
2022	415.00	812.00	1,315.00	2,542.00	1,194
2023	415.80	811.00	1,316.00	2,542.80	0.03

Table 1. Area harvested for cherry coffee in hectares in the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya from 2003 to 2023.

Source: SIAP: Historical data on planting and harvesting progress, 2003–2023

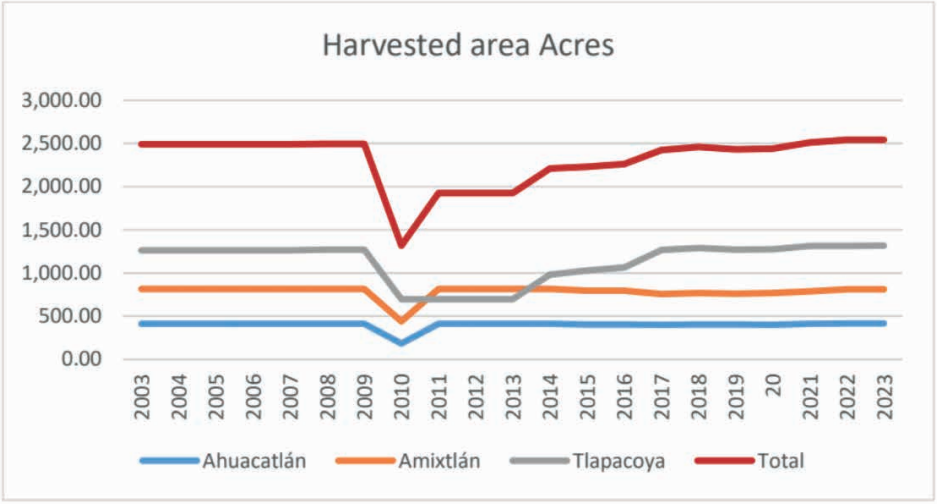

Figure 2. Area harvested for cherry coffee in the municipalities of the middle Laxaxalpan basin during the period 2003–2023.

Year	Ahuacatlán	Amixtlán	Tlapacoya	Total	Increases (%) + or -
2003	3.39	3.5	4.5	3.	-
2004	3.52	3.70	4.90	4.04	18.18
2005	4.10	3.99	5.00	4.36	**81.5295**
2006	3.60	3.50	3.30	3.47	3.1519
2007	3.80	4.00	3.20	3.67	-4.1462
2008	3.00	3.00	4.90	3.63	48.5443
2009	3.10	3.50	4.00	3.53	5.7886
2010	1.10	1.10	2.91	1.70	15.45
2011	2.00	2.40	3.00	2.47	11.8110
2012	3.00	3.50	6.00	4.17	**64.7362**
2013	3.00	3.00	4.00	3.33	-41.2788
2014	3.30	3.25	4.40	3.65	16.2862
2015	3.08	3.15	4.51	3.58	16.44
2016	1.50	1.70	3.59	2.26	12.8956
2017	1.38	1.35	3.60	2.11	2.9173
2018	1.60	1.60	3.42	2.21	-7.6743
2019	1.99	2.11	2.87	2.32	-10.1553
2020	2.25	2.21	2.81	2.42	7.2889
2021	2.45	2.42	2.35	2.41	-10.2900
2022	3.11	3.08	3.07	3.09	20.9635
2023	3.39	3.33	3.21	3.31	14.83

Table 2. Average yield per hectare of cherry coffee (ton/ha) in the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya for the analysis period 2003–2023

Source: SIAP: Historical data on planting and harvesting progress, 2003–2023

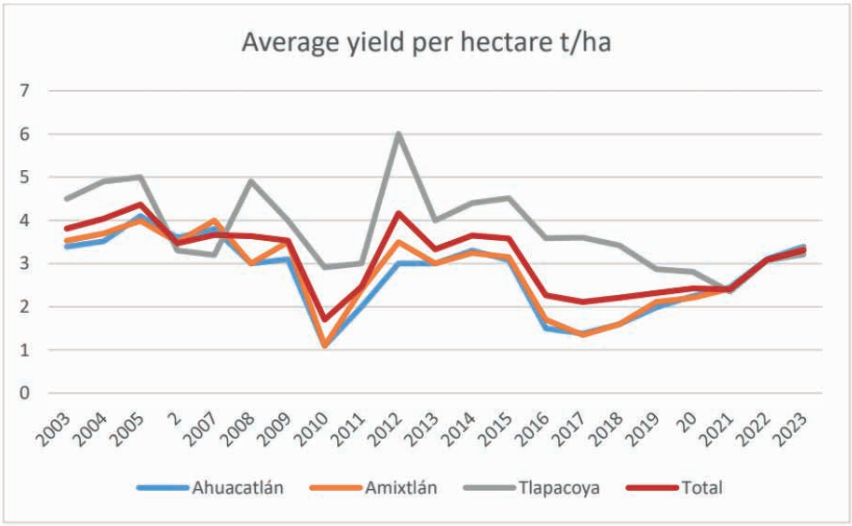

Figure 3. Average yields per hectare of cherry coffee in the municipalities of the middle Laxaxalpan basin, 2003–2023.

analyzed (16 times out of 21 years), with 2005 standing out with an increase of 81.5% over the previous year and 2012 with 64.7%. Conversely, the largest decreases were in 2013 and 2019, with figures of 41.3% and 10.2%, respectively.

At the basin level, the highest average yield was in 2005 with 4.4 tons/ha and the lowest in 2010 with 1.7 tons/ha, which also coincides with the year of reduction in cherry coffee harvest areas due to extraordinary frosts in the region.

Figure 3 shows the trend in average yields per hectare in each municipality, as well as the average yield.

The figure above shows that the coffee-growing municipalities in the middle Laxaxalpan basin have a downward trend in yields, indicating a lack of innovation and technological development in coffee plantations, with a consequent decline in yields, especially in the municipality of Tlapacoya.

The best equation describing the behavior of average yields per hectare in the Laxaxalpan middle watershed is a polynomial with the formula:

$$y = 0.0057x^2 - 0.195x + 4.371$$
$$R^2 = 0.3746$$

This does not have a good correlation due to fluctuations in average yields per hectare. The average yield per hectare in the three municipalities is slightly lower than that of the state of Puebla, by 1.78%.

ii) Production

Table 3 shows the coffee production generated during the 21 years of analysis in the three municipalities studied in the Laxaxalpan watershed.

Table 3 shows that during the period analyzed, the municipality that contributed the largest amount of cherry coffee was Tlapacoya, while Ahuacatlán contributed the least. In the study area, record production occurred in 2005 with 11,255 tons, a figure not reached again during the period. The lowest cherry coffee tonnage coincided with the drastic reduction in the area planted in Tlapacoya in 2010 with 2,714 tons, a decrease of 80.5% compared to the previous year.

Figure 4 shows the behavior of cherry coffee production in each municipality and the sum of the three.

The equation that best explains the trend in total cherry coffee production in the three municipalities of the Laxaxalpan basin is a polynomial whose formula is:

$$y = 27.47x^2 - 774.71x + 11810$$
$$R^2 = 0.4483$$

This is slightly acceptable in terms of correlation, due to strong variations in production from 2009 to 2012. The tonnage of cherry coffee from the three municipalities represents only 3.73% of the total production in the state of Puebla in 2023.

iii) Average rural price ($/ton)

Market prices in rural areas are a major factor in coffee growers' decision-making, as they encourage or discourage cherry coffee production. Table 4 shows the prices per municipality and the average for the Laxaxalpan basin for the 21 years of the study.

Table 4 shows that the average rural price of cherry coffee during the period analyzed was highest in the municipality of Tlapacoya, with the most significant increase in percentage terms occurring in 2005, at close to 80%. while the most significant decrease was in 2013, with more than 40%, which coincides with the recovery of coffee production in the area in 2012-2013.

Year	Ahuacatlán	Amixtlán	Tlapacoya	Total	Increases (%) + or -
2003	1,399.00	2,876.00	5,683.50	9,958.50	-
2004	1,453.00	3,014.00	6,187.70	10,655.70	7,0011
2005	1,690.00	3,250.00	6,315.00	11,255.00	5.6242
2006	1,488.24	2,852.50	4,167.90	8,572.72	5.5988
2007	1,571.00	3,260.12	4,041.60	8,872.72	4.2789
2008	1,237.95	2,444.25	6,218.10	9,900.30	11.5813
2009	1,279.22	2,851.63	5,076.00	9,206.85	-7.0043
2010	200.92	482.63	2,030.40	2,713.95	-80.5225
2011	825.30	1,955.40	2,094.00	4,874.70	**79.6164**
2012	1,237.95	2,851.63	4,188.00	8,277.58	69.8070
2013	1,237.95	2,444.25	2,792.00	6,474.20	-21.7863
2014	1,365.04	2,648.75	4,325.20	8,338.99	28.8034
2015	1,249.07	2,508.98	4,636.28	8,394.33	0.6636
2016	607.95	1,352.20	3,816.17	5,777.32	-32.1759
2017	552.00	1,020.60	4,564.80	6,137.40	6.2326
2018	664.80	1,228.00	4,412.64	6,285.44	2,4121
2019	799.98	1,603.60	3,644.90	6,048.48	-3,770
2020	900.00	1,692.86	3,579.94	6,172.80	2.0554
2021	1,009.40	1,906.96	3,083.20	5,999.56	-2.8065
2022	1,290.65	2,499.33	4,037.05	7,827.03	30.4061
2023	1,409.56	2,700.63	4,224.36	8,334.55	6.4842

Table 3. Cherry coffee production in tons in the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya during the analysis period 2003–2023.

Source: SIAP: Historical data on planting and harvesting progress, 2003–2023

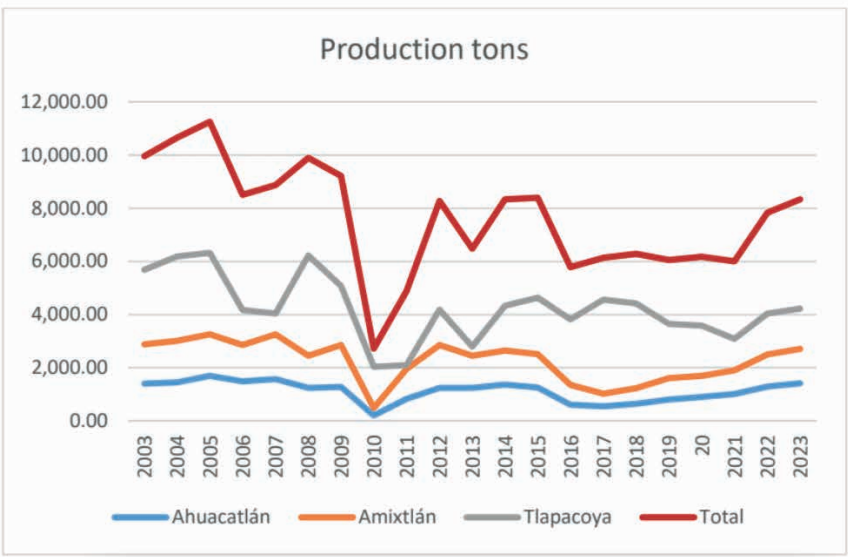

Figure 4. Production in tons of cherry coffee in the three municipalities and the total for the Laxaxalpan middle basin.

Year	Ahuacatlán	Amixtlán	Tlapacoya	Total	Increases (%) + or -
2003	1,000	1,000	1,300	1,100.00	
2004	1,300	1,300	1,300	1,300	18.18
2005	2,500.00	2,500	2,079.65	2,359.88	**81.5295**
2006	2,200.00	2,200.00	2,902.79	2,434.26	3.1519
2007	2,300.00	2,300.00	2,400.00	2,333.33	-4.1462
2008	3,000	3,000	4,398.10	3,466.03	48.5443
2009	3,500.00	3,500.00	4,000.00	3,666.67	5.7886
2010	3,800	3,900.00	5,000	4,233.33	-15.4545
2011	3,800	3,900	6,500.00	4,733.33	11.81
2012	8,000	8,200.00	7,192.54	7,797.51	64.7362
2013	5,000	5,000.00	3,763.39	4,578.80	-41.2788
2014	5,691.13	5,472.61	4,809.79	5,324.51	16.2862
2015	6,045.00	6,190.10	6,355.11	6,200.07	14.4440
2016	6,199.50	6,329.41	8,469.90	6,999.60	12.8956
2017	7,183.41	7,318.00	7,110.00	7,203.80	2.9173
2018	6,201.23	6,492.00	7,259.66	6,650.96	-7.6743
2019	6,025.21	6,271.03	5,630.38	5,975.54	-10,155.3
2020	6,583.64	6,714.36	5,935.11	6,411.04	7.2880
2021	5,548.42	5,610.55	6,095.06	5,751.34	-20.29
2022	6,967.50	6,870.04	7,033.54	6,957.03	20.9635
2023	7,900.00	7,950.00	8,117.61	7,989.20	14.8365

Table 4. Average rural price of cherry coffee ($/ton) in the municipalities of Ahuacatlán, Amixtlán, and Tlapacoya, and average rural price during the period (2003–2023).

Source: SIAP: Historical data on planting and harvest progress, 2003–2023

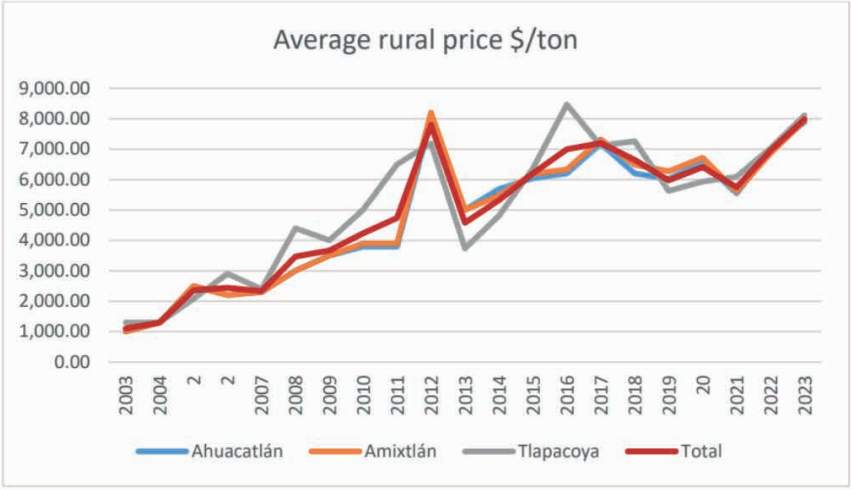

Figure 5. Average rural price ($/ton) of cherry coffee in the municipalities and its average in the Laxaxalpan basin.

Figure 5 shows the variations in average rural prices in the municipalities of the Laxaxalpan basin.

The graph above shows a positive slope and intertwining prices in the three municipalities, with the largest price difference between the average and that of the municipality of Tlapacoya.

The best curve to explain this trend is an exponential curve with the following formula:

$$y = 1007.9_{x}^{0.6749}$$
$$R^2 = 0.9191$$

The above equation has a high correlation.

During 2023, the average rural price of cherry coffee in the municipalities of the basin was 3.99% higher than the average price in the state of Puebla.

iv) Production value (thousands of dollars).

For this variable, market prices and deflated prices were used in order to compare them over time, taking into account the data provided by INEGI with the base year 2018 for this analysis (Table 5).

The table above shows that both at current (or market) values and at constant (or deflated) values, the period from 2010 to 2013 was characterized by price turbulence, with falls and rises reaching maximum and minimum values, with negative figures of 56% and positive figures of 172%, a situation that causes uncertainty among coffee growers in the Laxaxalpan basin.

Figure 6 shows the parallelism between the value of cherry coffee production at current and constant prices. At the beginning, current values are higher than constant values, but over time the gap narrows until the end of the study period base year 2018, when they equalize and constant values begin to exceed current values. The gap in the year of origin of the analysis (2013) between current and constant values is 2.16 times, favorable to constant values. At the end of the study period (2023), the gap becomes favorable to constant values at 1.27.

The value of cherry coffee production in the municipalities under analysis in 2023, at market prices, represented 3.89% of the value in the state of Puebla.

v) Average annual growth rates (%)

Table 6 shows the average annual growth rates of the selected variables over the 21-year project horizon.

Variables	Average annual growth rate (%)
Harvested area (ha)	0.10
Average yield per hectare (tonnes/ha)	-0.66
Production (tons)	-0.84
Average rural price ($/ton)	9.90
Production value at current prices (thousands $)	8.69
Production value at constant prices ($ thousands)	14.03

Table 6. Average annual growth rates for the period 2003–2023 for the selected variables.

Table 6 shows that the harvested area remained virtually constant throughout the period under review, with values indicating an increase of six tenths of a percentage point, which is not significant. The average yield per hectare is an indicator of progress in innovation and technological development, and in this case there was a decline of two-thirds of a percentage point. Cherry coffee production reflects a decrease of almost one percentage point. The average rural price throughout the analysis period shows growth of approximately ten percentage points. Finally, the value of production at current or market values increased by eight and a half percentage points. When considering constant

Year	Production value Current prices	Increases (%) + or	Production Value Constant Prices	Increases (%) + or -
2003	11,635.55		5,362.08	
2004	13,852.41	18,766.7	6,910.99	28.4074
2005	25,482.99	83.9607	13,461.69	94.7867
2006	21,648.17	-15.0485	12,134.31	-9.8604
2007	20,811.42	-3.8652	12,380.11	2.0257
2008	38,394.43	84,487.3	24,281.02	96.1293
2009	34,761.98	-9.5391	23,136.54	-4.7135
2010	12,797.76	-63.1846	8,890.29	-61,574.7
2011	24,373.20	90.4490	17,891.41	101.2466
2012	63,409.33	**160,1601**	48,660.54	**171,977.81**
2013	28,843.00	-54,5130	22,511.36	-55.7380
2014	43,067.50	49.3170	35,081.64	55.8197
2015	52,591.90	22.1151	44,221.73	26.0538
2016	44,656.53	-15.0886	39,831.39	-9.9280
2017	43,889.72	-1.7171	41,718.48	4.7377
2018	44,005.00	0.2627	44,005.00	5.4880
2019	35,398.44	-19.5581	36,927.30	-16.0839
20	38,539.09	8.8723	42,060.62	13.9012
2021	35,091.96	-8.9445	40,017.62	-4.8523
2022	54,557.85	55.4711	66,258.10	65.5723
2023	66,897.24	22.6171	84,867.24	28,058

Table 5. Value of cherry coffee production (thousands of dollars) at market prices and deflated with base year 2018 for the three municipalities of the Laxaxalpan basin in the period 2003 to 2023.

Source: SIAP: Historical data on planting and harvest progress 2003 - 2023

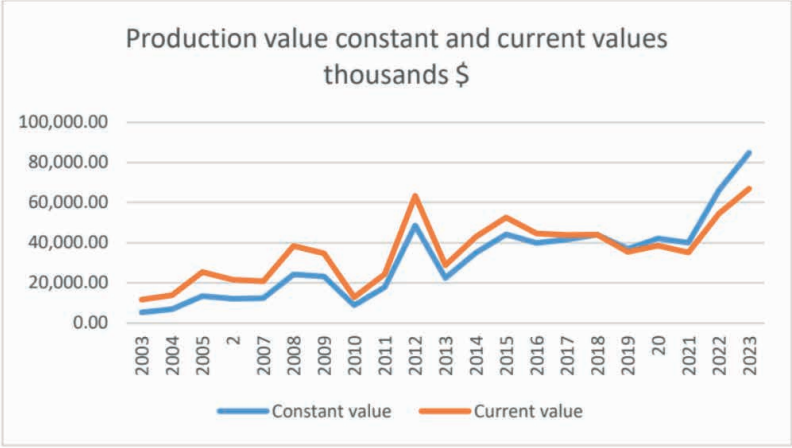

Figure 6. Total production values at current and constant values in the Laxaxalpan basin.

	Total population			Eco Act Pop			EAP Fem		EA Mas	
Municipality	2000	2010	2020	2000	2010	2020	2010	2020	2010	2020
Ahuacatlán	13,058	14,754	14,542	3,643	4,764	6,757	1,140	2,674	3,624	4,083
Amixtlán	4,704	5,004	4,812	1,338	1,397	1,569	261	440	1,136	1,129
Tlapacoya	6,502	6,406	6,422	2,550	1,961	2,831	307	974	1,654	1,857
Total	24,264	26,164	25,776	7,531	8,122	11,157	1,708	4,088	6,394	7,069

Table 7. Total population (TP), economically active population (EAP), female economically active population (FEAP), and male economically active population (MEAP) in the cherry coffee-producing municipalities of the Laxaxalpan basin.

Source: National Population Council (2000-2010-2020). No data available for 2000 for female and male economically active population.

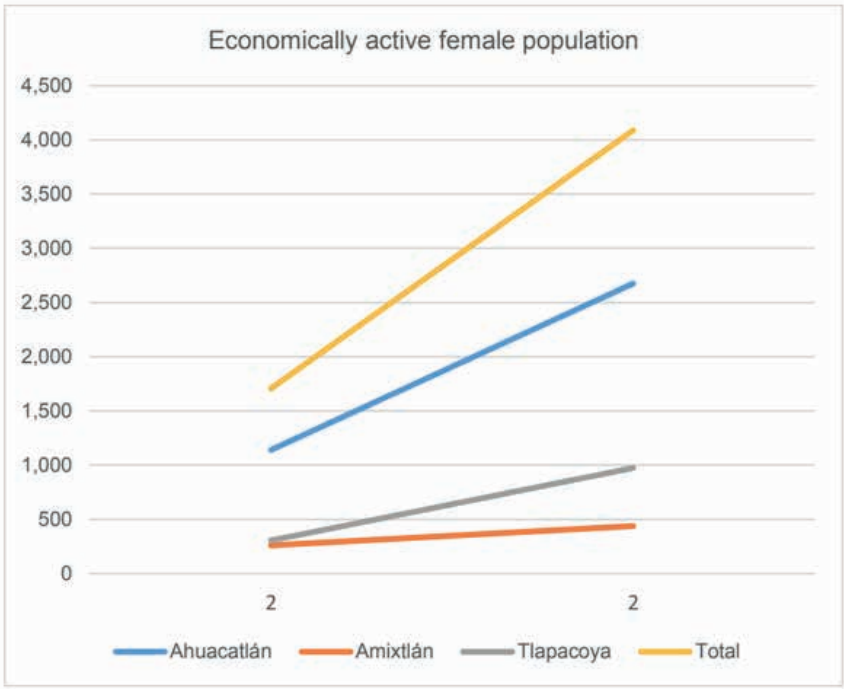

Figure 7. Evolution of female labor participation in the three municipalities studied in the middle Laxaxalpan basin.

prices, growth was 14 percentage points.

vi) Total population (TP) and economically active population (EAP).

Table 7 shows the total population and the economically active population, both female and male, in the three selected municipalities of the Laxaxalpan basin.

Table 7 shows that 43.3% of the total population in the selected municipalities of the Laxaxalpan basin is employed. The municipality of Ahuacatlán has the highest proportion of the economically active population, at 65.1%. The increase in women's participation in the labor force is significant, rising from 21% in 2010 to 36.6% in 2020 in the study region.

Figure 7 shows the growth of female labor force participation within the economically active population of the study region.

In the figure above, the three municipalities, like the total, have a positive slope, highlighting the evolution and growth of the female labor force in the municipality of Ahuacatlán. This situation does not occur with the male labor force, whose growth is lower, mainly due to emigration to more developed population centers or foreign- . Based on the National Occupation and Employment Survey (ENOE. INEGI. 2023), in the state of Puebla, the economically active population engaged in primary sector activities was 29.5%. Applying this indicator to the economically active population of the selected municipalities, this represents around 3,283 workers, who contribute a monetary value of $66.9 million pesos from cherry coffee cultivation.

CONCLUSIONS

The area harvested for cherry coffee during the period analyzed reflects a decline due to climatic conditions and prices that were not attractive to coffee growers.

The average yield per hectare and cherry coffee production in the selected municipalities of the Laxaxalpan basin fell slightly. Coffee yields in the study area show a lack of dynamism in innovation and technology adoption in coffee farming, with consequent stagnation in cherry coffee production.

The value of cherry coffee production is important at the regional level, especially when the economically active population is small in relation to the total population.

Women's participation in economic activities is increasing in the selected municipalities due to the emigration of the male population.

REFERENCES

Addin Technology Incorporated. (2018). How to calculate average/compound annual growth rate in Excel? ExtendOffice. https://www.extendoffice.com/es/documents/excel/2596-excel-average-compound-growth-rate.html

Consejo Nacional de Población (2000-2010-2020). Sin datos del año 2000 para PEA Femenina y PEA Masculina.

Instituto Nacional de Estadística y Geografía. (2000). Censo de Población y Vivienda 2000. https://www.inegi.org.mx/programas/ccpv/2020/#datos_abiertos

INEGI. (2010). Censo de Población y Vivienda 2010. Instituto Nacional de Estadística y Geografía. https://www.inegi.org.mx/programas/ccpv/2010/#datos_abiertos

INEGI. (2020). Censo de Población y Vivienda 2020. Instituto Nacional de Estadística y Geografía. https://www.inegi.org.mx/programas/ccpv/2020/

Instituto Nacional de Estadística y Geografía. (2023). Encuesta Nacional de Ocupación y Empleo (ENOE), 2023. https://www.inegi.org.mx/programas/enoe/

Secretaría de Recursos Hidráulicos (SRH). (1970). Estudio Hidrológico de la Cuenca del Río Laxaxalpan. Recuperado de mydokument.com.

Secretaría de Agricultura y Desarrollo Rural. (2023). Sistema de Información Agropecuaria y Pesquera: Histórico de avance de siembras y cosechas 2003–2023. https://www.gob.mx/

Secretaría de Agricultura y Desarrollo Rural. (2024 p. 48-49). Panorama agroalimentario 2018–2024: La ruta de la transformación agroalimentaria. Servicio de Información Agroalimentaria y Pesquera (SIAP).

Universidad Autónoma de Chapingo. (2007). Ordenamiento Ecológico de las Cuencas Hidrológicas de los Ríos Necaxa y Laxaxalpan. Recuperado de HYPERLINK "https://agua.org.mx/biblioteca/ordenamiento-de-las-cuencas-de-los-rios-necaxa-y-laxaxalpa/"agua.org.mx.National Institute of Statistics and Geography. (2023). National Occupation and Employment Survey (ENOE), 2023. https://www.inegi.org.mx/programas/enoe/

Secretariat of Water Resources (SRH). (1970). Hydrological Study of the Laxaxalpan River Basin. Retrieved from mydokument.com.

Ministry of Agriculture and Rural Development. (2023). Agricultural and Fisheries Information System: History of planting and harvesting progress 2003–2023. https://www.gob.mx/

Ministry of Agriculture and Rural Development. (2024, pp. 48–49). Agri-food outlook 2018–2024: The path to agri-food transformation. Agri-Food and Fisheries Information Service (SIAP).

Autonomous University of Chapingo. (2007). Ecological Management of the Necaxa and Laxaxalpan River Basins. Retrieved from agua.org.mx.