Typology of coffee producers in Tlachichilco, Veracruz, Mexico

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ABSTRACT

Objective: To characterize the coffee-growing units in the municipality of Tlachichilco, Veracruz, Mexico, in order to establish a typology of producers and identify key characteristics to inform public policy development.

Design/methodology/approach: Data were obtained through semi-structured surveys applied to n=54 coffee producers in Tlachichilco, Veracruz, selected using convenience sampling. A Principal Component Analysis (PCA) was conducted, and a Technological Index (TI) was estimated. For the cluster analysis, the Cluster procedure and Ward's method from the SAS statistical package were used.

Results: Three types of coffee producers were identified: subsistence (64.8%), intermediate (29.6%), and transitional (5.5%). The subsistence group showed the lowest yield, income, and technological index, while the transitional group had the highest yield and income, reaching 1,400 kg/ha and 42,000 pesos per year, respectively. The lowest technological index was found in the subsistence and transitional groups, while the intermediate group displayed characteristics between the first and third groups.

Limitations of the study/implications: The typology of producers was established specifically for Tlachichilco; therefore, similar studies are needed in other coffee-producing regions of Veracruz.

Findings/conclusions: Coffee producers face productive and economic limitations, resulting in a predominantly subsistence-oriented coffee sector. To increase production, it is necessary to adopt technologies that help control weeds, pests, and diseases, along with continuous training.

Keywords: Technological index, subsistence, transition, main components.

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INTRODUCTION

Coffee production (*Coffea arabica* L.) is important for the economies of developing countries, as its cultivation, processing, transportation, and commercialization generate millions of jobs worldwide (SADER, 2022). The topography, altitude, climate, and soils of Mexico enable the production of high-quality coffee and the development of varieties ranked among the best in the world, making coffee one of the main agricultural export products of the country.

In 2022, global coffee production reached 170 million 60-kg bags (USDA, 2024), with five countries accounting for 73% of total output: Brazil produced 36.8% of the global supply, Vietnam 17.5%, Indonesia 7%, Colombia 6.6%, and Ethiopia 4.9%. In the same year, Mexico ranked eleventh (SIAP, 2023).

In Mexico, two types of coffee plants are cultivated: *Coffea arabica*, which occupies the largest area with 95% of total cultivation, and *Coffea canephora* (commonly known as Robusta), which is gradually expanding its cultivated area and is primarily used for the production of instant coffee (Escamilla *et al.*, 2021). The Arabica variety grows at altitudes ranging from 500 to 2,000 meters above sea level, has a mild flavor, and contains 1.5% caffeine; in contrast, Robusta contains 2.5% caffeine and has a more bitter taste (SADER, 2015). In 2024, the main coffee-producing states in Mexico were Chiapas, Veracruz, and Puebla, with 393,000, 256,000, and 228,000 tons, respectively, accounting for 83% of the country's total production (SIAP, 2024).

In Veracruz, coffee production takes place in 82 municipalities where approximately 86,000 producers reside, including Indigenous peoples such as the Náhuatl, Totonac, and Popoluca. The main characteristics of coffee production in the state are as follows: it is carried out on small plots located in highland areas; production units are situated in Indigenous regions with varying degrees of poverty and marginalization; many families depend on this activity for their livelihood; and coffee production is a significant source of foreign exchange (Hermida, 2018).

There are three main coffee-producing regions in Veracruz: the northern region, which includes Huayacocotla and Papantla; the central region, which comprises Atzalan, Misantla, Coatepec, Huatusco, Córdoba, and Zongolica; and the southern region, where Tezonapa and Los Tuxtlas are located. Among the coffee-producing municipalities in the state, 23% have Indigenous populations and are classified as areas of high or very high marginalization; additionally, these municipalities report the lowest *per capita* income in the state. Of all the municipalities, fifteen are of industrial importance and are located in the metropolitan areas of Córdoba and Orizaba (Gobierno del Estado de Veracruz, 2019).

Tlachichilco is located in the northern region of the state of Veracruz and is a coffee-producing municipality. It covers an area of 226 km^2, comprises 64 communities, and has a population of 10,900 inhabitants, of whom 48.7% are men and 51.3% are women. The municipality is situated at an altitude of 790 meters above sea level, and most of the population lives in rural areas, where seasonal migration is common due to limited employment opportunities in agriculture.

Coffee production units in Veracruz are characterized by their heterogeneity, limited technical and financial capacity, and marketing challenges (Ávila-Foucat, 2017). Producer typology is one of the most commonly used tools for designing targeted programs in the agricultural sector, and its success depends on the effectiveness of appropriate stratification (Ruiz-Ramírez *et al.*, 2020). Heterogeneous producers within the same geographical region should not be treated as a homogeneous group; instead, differentiated agricultural policies should be developed, and typologies should be created to identify the strengths and limitations of each group of producers (Cuevas *et al.*, 2019). Therefore, the objective of this study was to develop a typology of coffee production units in the municipality of Tlachichilco, in northern Veracruz, as a basis for identifying differences among producers and analyzing the economic activity in order to design public policies that improve the quality of life of the local population.

MATERIALS AND METHODS

The study was conducted in the municipality of Tlachichilco, located in the northern region of the state of Veracruz. A structured questionnaire divided into seven sections was used to carry out the research. It included the identification of the producer, characterization of the family fruit production unit, marketing, other relevant data supporting coffee cultivation, availability of resources and infrastructure, and the technical-productive characterization. Data collection took place from January to March 2022 through a questionnaire administered to small-scale producers with coffee farms.

The statistical sample was calculated using data from a registry of n=125 coffee producers in the municipality. The sampling design was determined based on finite population sampling (Aguilar-Barojas, 2005), using the following formula:

$$n = \frac{(p)(q)(N)(z^2)}{E^2(N-1)+z^2(p)(q)} \quad 1)$$

Where N is the total population of the study area, consisting of 125 coffee producers; n is the sample size; p is the estimated percentage of positive variability: 50%; q equals $100-p$ (negative variability); E is the allowed estimation error or precision (10%); and z is the confidence level, with z from tables equal to 1.96. Substituting these values, the following sample size was obtained:

$$n = \frac{(0.50)(0.50)(125)(1.96^2)}{0.1^2(125-1)+1.96^2(0.50)(0.50)} = 54 \text{ questionnaries} \quad 2)$$

A total of 54 questionnaires, including quantitative and qualitative variables, were administered. Data collection used a non-probabilistic convenience sampling method, since producers were included based on their availability to be interviewed until the required number of interviews was completed. Communities with the highest coffee production index were considered as the stratification criterion.

Data obtained from the questionnaire were recorded in Excel spreadsheets and then exported for further analysis. To reduce the dimensionality of the variables, a Principal Component Analysis (PCA) was performed, using variables selected by the program to identify interdependencies among variables (Tharwat, 2016).

To complement the information from the principal components, a Technological Index (TI) was developed. At the technological level, knowledge of activities and applied science through technological innovation has allowed developed countries to increase productivity and reduce costs (Mejía and Ramírez, 2015). Agricultural technology has features that promote efficient and sustainable farming methods, helping farmers to thrive in today's industry. Using information obtained from the producers, a Technological Index (TI) was calculated, defined by three components (Benítez-García *et al.*, 2015; Rosales-Martínez *et al.*, 2018).

The first component was agricultural practices and pest control, which was assigned a weighting of 0.50 and is composed of five activity subcomponents: a) Soil analysis (with a weighting of 0.20); b) Weed control (0.20); c) Pest and disease control (0.20); d) Pruning (0.20); and e) Fruit thinning (0.20). The second component, corresponding to crop and species management activities, was assigned a weighting of 0.25, and includes five subcomponents: a) Clearing (with a weighting of 0.20); b) Raised beds or ridges (0.20); c) Preparation of planting holes (0.20); d) Transplanting (0.20); and e) Planting pits on ridges (0.20). The third component corresponds to species and varieties, considering the number of varieties with or without resistance to pests and diseases, and was assigned a weighting of 0.25; it has three subcomponents corresponding to the following varieties: a) Costa Rica (0.25); b) Oro Azteca (0.50); and c) Typica or Criolla (0.25). The sum of the weightings in each principal component (0.50, 0.25, and 0.25) equals 1; and the sum of the subcomponents in each component also equals 1.

To describe the characteristics of the producers, a principal component analysis (PCA) was performed using the SAS statistical package. A correlation matrix between variables and a mean difference test were generated. The data analysis consisted of descriptive analysis followed by a mean difference test. The Kaiser criterion was used to determine the number of components, including only those with eigenvalues greater than 1 (Demey *et al.*, 1994). For the PCA, 11 variables measuring productive and socioeconomic aspects of the producers were considered.

The variables analyzed were as follows: age, years of schooling, total land area, percentage of self-consumption, membership in a producers' organization, species or varieties cultivated, area planted with coffee, yield in the last year, coffee price, income from coffee sales, and technological index. For the cluster analysis, the Cluster procedure and Ward's method from the SAS statistical package were used.

RESULTS AND DISCUSSION

Of the 54 producers interviewed in the study region, 85% were male and 15% female, with an average age of 62 years for both sexes. This variable ranged from a minimum of 32 to a maximum of 88 years (Table 1), which aligns with the maximum age reported by Dussán-Lubert (2006). The schooling level of coffee producers in the municipality of Tlachichilco averaged 4.1 years of study, corresponding to a basic education level up to the fourth grade of primary school, similar to that reported by Benítez-García *et al.* (2015) in a study conducted on coffee growers in Cuetzalan, Puebla.

The average land area available to the producers was 3.8 ha. This low average corresponds to subsistence agriculture, where most producers cultivate maize, beans, cinnamon, and coffee —the latter being harvested for sale. However, according to Benítez-García *et al.* (2015), the coffee-growing area is characterized by smallholder producers. In the municipality of Tlachichilco, producers have on average 1.4 ha planted with coffee. They consider coffee cultivation as a complementary economic activity to their income. Producers in this region diversify their activities in other sectors to obtain additional income and thereby meet the basic needs of their families.

Table 1. Statistics of the socioeconomic variables used in the study.

Variable	Description	Mean	Standard Deviation	Minimum	Maximum
X1	Age (years)	62.5	13.4	38	84
X2	Schooling (years)	4.1	3.9	0	15
X3	Total land area (ha)	3.8	1.5	1	8
X4	Percentage of self-consumption (kg)	15	9.7	0	50
X5	Years of experience in coffee production (years)	22.4	12.8	2	50
X6	Coffee varieties handled (1,2,3)	1.9	0.6	1	3
X7	Coffee-planted area (ha)	1.4	0.6	0.3	2
X8	Yield (kg/ha)	417.1	411.9	0	1500
X9	Coffee selling price ($/kg)	18	11.7	5	35
X10	Coffee sales revenue ($)	10,070	13,187	0	52,500
X11	Technological index	2	1	0.5	3.5

Source: prepared by the authors with field data.

The average length of time producers have been dedicated to coffee-growing activities in the region is 22 years. Most are experienced coffee growers, a result similar to that reported by Vázquez-López *et al.* (2022) for coffee producers in northern Chiapas, where 36% of surveyed producers have between 11 and 22 years of experience in coffee production.

For the interpretation of variables, Principal Component Analysis (PCA) was used. This method transforms multidimensional information into a few variables that explain a large part of the fluctuations of the original variables, as well as their interrelationships.

According to the criterion of including only those values greater than 1, three principal components were selected (Table 2), which explain 69.58% of the variation among coffee producers. As these values drop below one, the proportion of variance becomes less significant (Amat, 2017).

Table 2. Proportion of absolute and cumulative variance of the principal components.

Variable	Eigenvalue	Difference	Proportion	Cumulative
X1	4.4762	2.5022	0.4069	0.4069
X2	1.9740	0.7706	0.1795	0.5864
X3	1.2034	0.3523	0.1094	0.6958
X4	0.8511	0.1762	0.0774	0.7732
X5	0.6749	0.1140	0.0614	0.8345
X6	0.5609	0.1409	0.0510	0.8855
X7	0.4200	0.0145	0.0382	0.9237
X8	0.4055	0.1474	0.0369	0.9605
X9	0.2581	0.1131	0.0235	0.9840
X10	0.1450	0.1141	0.0132	0.9972
X11	0.0309		0.0028	1.0000

From the three main values of the correlation matrix, variables were constructed to determine the principal components. Principal Component 1 (PC1) explains 40.69% of the total variance and largely reflects the differences between producers and their production systems. Principal Component 2 (PC2) accounts for 17.95% of the variance, while Principal Component 3 (PC3) explains 10.9% of the variance.

Table 3 describes the characteristics by component of the coffee producers. The dominant variables for the first group (PC1) were identified as the age of the producers (X1), the experience in coffee production (X5), the area planted with coffee (X7), production yield (X8), the selling price of coffee (X9), and income from coffee sales (X10). According to SAGARPA (2014), in rural areas the aging of the population has been more pronounced, mainly due to the migration of young people in productive age. Ramírez *et al.* (2023) report that the coffee harvest runs from January to May, with the heaviest picking occurring from mid-February to mid-March; during these months, conditions of lower temperature, precipitation, and relative humidity prevail. Another important factor in this component is the technological index, which encompasses the cultural practices carried out by coffee producers. As Hernández-Ruíz *et al.* (2018) point out, the technological index is considered the basis for defining strategies that contribute to achieving better performance of the production system.

The second group, CP2, is represented by the variables (X2) and (X9), corresponding to the producer's level of education and the coffee selling price. De Brito *et al.* (2018) report that education is a determining factor for improving the quality of life of rural inhabitants. In the municipality of Tlachichilco, most producers have an education level equivalent to primary school. Galindo (2007) mentions that age and level of education determine the degree of acceptance and adoption of new technologies for the development of agricultural crops in Zacatecas; younger producers with higher levels of education are more willing to implement technological recommendations. The

Table 3. Correlation matrix for the three most relevant principal components.

Variable	CP1	CP2	CP3
X1	0.3017	−0.3735	0.1541
X2	−0.2096	0.4746	0.1754
X3	0.1480	−0.4143	−0.3177
X4	0.2493	0.1668	−0.4999
X5	0.3239	−0.3443	−0.0182
X6	0.0687	−0.2508	0.6241
X7	0.3877	0.0600	−0.0015
X8	0.3961	0.1686	0.2098
X9	0.3068	0.3530	0.1184
X10	0.3924	0.2283	0.2600
X11	0.3407	0.2134	−0.2815

CP1: Principal Component 1; CP2: Principal Component 2; CP3: Principal Component 3.

coffee selling price (variable X9) characterizes the producers in Group 2. In the region, the price of coffee is determined by intermediaries according to supply and demand conditions. A similar study conducted by Tomas-Torres *et al.* (2018) in a community in the state of Guerrero points out that intermediaries pay very low prices; during each harvest there is uncertainty due to price fluctuations, and there is no organization to carry out marketing. Additionally, the coffee producers do not add value to the beans to improve the product's price.

For component CP3, the dominant variables describing the group of producers are income obtained (X10) and coffee variety (X6). According to Tablas *et al.* (2021), the main problems affecting coffee production and marketing are phytosanitary issues, technical challenges, market difficulties, and poor organization. The results of the component characteristics highlight the lack of organization among the producers.

The data resulting from the principal component analysis were used for cluster integration. The Ward method was applied to minimize variation within groups and to obtain well-defined clusters. The clustering technique allowed the definition of three groups of producers: 1) Subsistence; 2) Intermediaries; and 3) In transition.

The results presented in Table 4 represent the existence of three types of producers classified as smallholders. Rojas-Herrera and Olguín-Pérez (2018) point out that this type of producer needs to organize collectively to strengthen their individual efforts and face competition. The findings regarding the number of typologies identified in this research are similar to those reported by Rosales-Martínez *et al.* (2018) for the Fortín District, Veracruz; by Leguizamo *et al.* (2023) for the municipality of Temascaltepec, State of Mexico; and by Merlín-Uribe *et al.* (2018) for the Sierra Madre of Chiapas. The latter study identified three typologies of coffee growers and analyzed the relevance of the role of women and youth in the productive and survival strategies in smallholder coffee farming. The results of the typologies found show a relationship between the cultivated area and the technological level of the producers. Given the resource constraints and the socioeconomic context of the producers, similarities can be identified among coffee growers at the national level.

Table 4. Main variables by type of producers in the municipality of Tlachichilco, Veracruz.

Variable	Group 1	Group 2	Group 3
	64.80%	**29.60%**	**5.50%**
	Subsistence	**Intermediates**	**In transition**
Age (years)	58.8	62.2	56
Schooling (years)	4.5	3.3	3
% of self-consumption	12	20.9	18.3
Coffee varieties	1.7	2	2
Coffee area (ha)	1.2	2	2
Yield (t ha^{-1})	160.7	793.7	1,400
Coffee sale price (\$ kg^{-1})	12.6	26.5	35
Sales revenue (\$)	1,908.2	20,625	49,000
Technological index	1.5	2.8	3.0

Group 1, corresponding to subsistence producers, comprises 64.8% of the coffee growers and the most important characteristics are as follows. The average age of this group is 58 years, similar to the 56 years reported by Benítez-García *et al.* (2015) for coffee producers in Cuetzalan, Puebla. The average schooling is 4.5 years of study. The main coffee variety they cultivate is Costa Rica 95, which is characterized by its resistance to rust and high productivity (Escamilla *et al.*, 2015). The average cultivated area is 1.2 ha, consistent with Ruiz-García *et al.* (2020), who report that 95.4% of all coffee producers fall into the category of smallholders with cultivated areas not exceeding 3 ha.

The coffee yield obtained in Group 1 is 360.7 kg per hectare, similar to that reported by Leguizamo-Sotelo *et al.* (2023) for the municipality of Sultepec, State of Mexico. The coffee variety influences the selling price; in this group, the Costa Rica variety stands out. These plants are short in stature, have bronze-colored shoots, high productivity, and good adaptability in areas ranging from 800 to 1,400 meters above sea level (Julca-Otiniano *et al.*, 2023).

The average price of green coffee of the Costa Rica variety is 12.60 pesos per kilogram and is sold in sacks of 25 and 50 kg. Despite the low yields obtained by this group, the producers consider coffee cultivation an important activity that generates income for their families throughout the year.

Group 2, considered the intermediate group, comprises 29.6% of the producers. The average age of this group is 62 years. The average schooling level is 3.3 years, indicating incomplete primary education and significant educational lag for this type of producer. Camero and Del Pino (2021) point out that low schooling is a limitation for the adoption of new technologies.

The average technological index in this group is 2.8, higher than that of Group 1. The average price per kilogram of coffee is 26.5 pesos for the Oro Azteca variety, with an annual income of 20,625 pesos, representing more of a subsistence option than wealth accumulation.

According to Rosales-Martínez *et al.* (2018), there is an urgent need to implement strategies for the reproduction of their coffee agroecosystems and to reduce vulnerability to situations such as the drop in international coffee prices, as well as environmental and plant health contingencies.

Group 3, called the transitional group, includes 5.5% of the producers. The average age is 56 years, similar to Group 1. This group has the highest average income from coffee sales, amounting to 42,000.00 pesos in 2022. The selling price for the Oro Azteca variety is 28.00 pesos per kg, similar to that reported by Benítez-García *et al.* (2015e) for coffee producers in Cuetzalan, Puebla, where prices ranged from 25.93 to 29.93 pesos per kg.

It is also similar to the findings of Orona-Castillo *et al.* (2024), who reported that the main problems for producers are the low prices received for their products, coffee marketing, and the long distances they must travel to manage their coffee plantations. The technological index for Group 3 was 3, higher than that observed in Groups 1 and 2.

In this study region, producers across all three groups lack technology for production; activities are carried out using only the basic necessities for cultivation. Therefore, it is necessary to provide specialized technical advice and continuous training for coffee

plantation renewal, as well as to promote the use of machinery and equipment technology to modernize production processes (Villareal, 2023).

CONCLUSIONS

Through principal component analysis, three types of coffee producers were identified in the municipality of Tlachichilco, Veracruz. The first group, called subsistence producers, comprises more than 60% of the producers; they cultivate the Costa Rica 95 variety on plots smaller than three hectares with low yields. The second group, called intermediate producers, represents nearly one-third of the producers and is characterized by having a Technological Index below the average. The third group, called transitional producers, accounts for 5.5% and includes producers with the highest income as well as the highest price for the Oro Azteca variety. For the three groups of coffee producers, age was a dominant factor; the majority are older producers who are encouraging new generations to work in the coffee plantations with the goal of increasing income. The typology of producers provides useful information for decision-making aimed at defining activities to enhance the development of the main producing areas.

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