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Research article

Coffee agroforestry systems in indigenous communities: a study case in *San Luis Acatlán*, state of *Guerrero*

Sistemas agroforestales de café en comunidades indígenas: un estudio de caso en San Luis Acatlán, Guerrero

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Abstract

Coffee farming in Mexican indigenous communities is developed under agroforestry systems (AFS) that function as biodiversity reservoirs and biocultural refuges. In order to update technical information regarding subsistence coffee farming in indigenous regions, the objective of this study was to identify and characterize coffee AFS in *Pascala del Oro* and *Arroyo Cumiapa* communities, in *San Luis Acatlán*, *Guerrero*, considering socio-ecological aspects. The methodology integrated a social approach through 75 questionnaires and a structural vegetation analysis in 35 plots by transects, in which diversity was quantified with the Shannon-Wiener and Simpson indexes. Results allow these systems to be classified as mountain-rustic, with a medium-to-high diversity. The *Pascala del Oro* community, inhabited by the *Me'phaa* ethnic group, stood out for its autonomous management, featuring 96 % seedling self-management, the use of resistant varieties and total compliance with soil conservation works. In contrast, the *Arroyo Cumiapa* community, of *Tu'un Savi* origin, showed structural vulnerability due to the overaging of coffee plantations, dependence on external support and technical lag. Although the Shannon-Wiener index was slightly higher in *Arroyo Cumiapa* (2.27), the Simpson index revealed a high dominance of native species from *Quercus* spp. and *Pinus* spp. in both areas. While these AFS guarantee food security and biological conservation, their long-term sustainability requires public policies that promote generational renewal and integrated phytosanitary management.

Keywords: Agrobiodiversity, biocultural conservation, indigenous identity, traditional management, rustic systems, sustainability.

Resumen

La producción de café en comunidades indígenas de México se lleva a cabo mediante sistemas agroforestales (SAF) que funcionan como reservorios de biodiversidad y refugios bioculturales. Ante la necesidad de actualizar la información técnica sobre la cafeticultura de subsistencia en regiones indígenas, el objetivo de este estudio fue identificar y tipificar los SAF de café en las comunidades de Pascala del Oro y Arroyo Cumiapa, en San Luis Acatlán, Guerrero, con base en aspectos socioecológicos. La metodología integró un enfoque social mediante 75 cuestionarios y un análisis estructural de la vegetación de 35 parcelas a través de transectos, en los que se determinó la diversidad con los índices de *Shannon-Wiener* y *Simpson*. Los resultados clasifican a estos sistemas como rústicos de montaña con una diversidad de media a alta. La comunidad de Pascala del Oro, habitada por la etnia *Me'phaa*, destacó por una gestión autónoma con 96 % de autogestión de plántulas, uso de variedades resistentes y cumplimiento total en obras de conservación de suelo. En contraste, Arroyo Cumiapa, de origen *Tu'un Savi*, presentó vulnerabilidad estructural debido al envejecimiento de los cafetales, dependencia de apoyos externos y rezago técnico. Aunque el Índice de *Shannon-Wiener* fue ligeramente superior en Arroyo Cumiapa (2.27), el Índice de *Simpson* reveló una alta dominancia de especies nativas de *Quercus* spp. y *Pinus* spp. en ambas zonas. Los SAF garantizan la seguridad alimentaria y la conservación biológica, pero su sostenibilidad a largo plazo requiere políticas públicas que fomenten la renovación generacional y la gestión fitosanitaria integral.

Palabras clave: Agrobiodiversidad, conservación biocultural, identidad indígena, manejo tradicional, sistemas rústicos, sostenibilidad.

Introduction

In Mexico, coffee (*Coffea arabica* L.) is primarily cultivated under shaded agroforestry systems in regions of high biodiversity. Around 70 % of these production units operate under traditional management and agroforestry systems led by small-scale and Indigenous producers (Flores-Ortiz et al., 2025). These systems are fundamental for conserving soil quality, water resources, and maintaining biological corridors, which boast high diversity and can contain up to 60 tree species per hectare (Moguel & Toledo, 1999).

However, the structure and composition of these coffee plantations are conditioned by the producer's decisions in the face of economic and environmental constraints. In many cases, the original canopy is replaced by fruit trees, timber trees, or species of the genus *Inga*, resulting in monospecific shade trees that, although maintaining a structure similar to the forest, alter the original biological richness (López-Gómez et al., 2008).

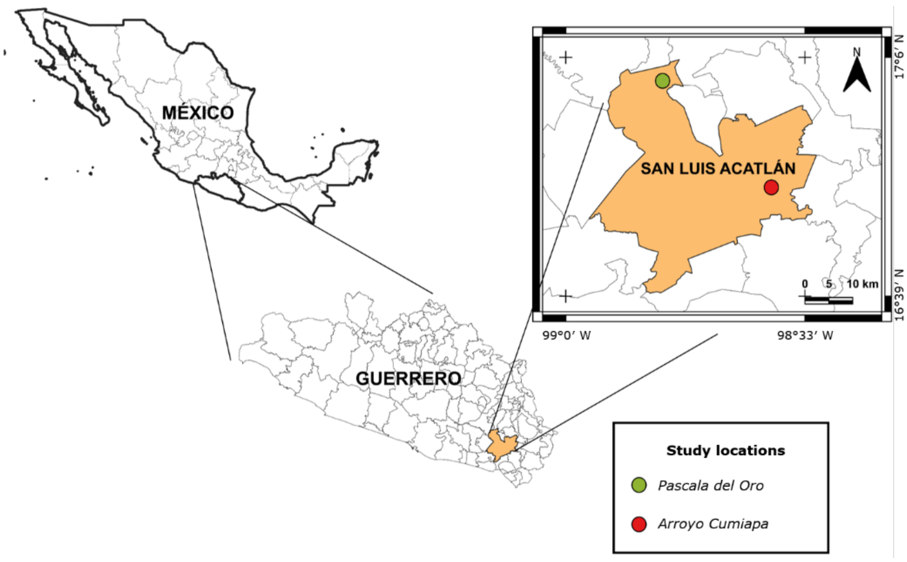
In the state of *Guerrero*, coffee production is concentrated in the *Costa Grande*, *Montaña* and *Costa Chica* regions, which make up 82 % of the state's production (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2022). Specifically, in 2013, *San Luis Acatlán* amounted for 3 211 producers and 4 414 production units on 2 034.82 hectares (Fierro-Leyva, 2019). Despite its importance, records on the current situation of the sector lack technical updates and public policies that promote its development.

In these communities, of *Tlapaneco* and *Mixteco* origin, subsistence coffee farming faces critical challenges such as pests, low profitability, lack of official incentives (Oropeza-Guevara et al., 2023), and a clear lag in updating its technical information. With the aim of generating a foundation to guide public policy and local development, this study sought to identify the types of coffee agroforestry systems in two indigenous communities of *San Luis Acatlán*, based on their social, technical, and structural components, as well as species composition.

Materials and Methods

Study area

The research was conducted in the Indigenous communities of *Pascala del Oro* and *Arroyo Cumiapa*, located in *San Luis Acatlán* municipality, in the state of *Guerrero*. The area is geographically located between 16°32' and 17°15' N and 98°31' and 98°51' W (Figure 1). The region has a climatic gradient from temperate humid to warm sub-humid, with vegetation composed of pine and pine-oak forests, and low deciduous forest (Instituto Nacional de Estadística, Geografía e Informática [INEGI], 2010).



México = *Mexico*; *Guerrero* = *Guerrero* state; *San Luis Acatlán* = *San Luis Acatlán* municipality. Source: Prepared by the author using information from INEGI (2010).

Figure 1. Location of the study area.

Social and technical diagnosis

The social and technical diagnosis consisted of a non-probabilistic, targeted sampling to administer semi-structured questionnaires to local producers. In *Pascala del Oro*, 25 beneficiaries of the *Sembrando Vida* (Sowing Life) program, integrated into a Farmer Learning Community (*CAC*, for its acronym in Spanish), were surveyed, representing 100 % of the total active members of such unit. Meanwhile, in *Arroyo Cumiapa*, 50 questionnaires were applied to producers in the *Guerrero* State Coffee Council (*Cecafé*, for its acronym in Spanish) registry, covering 90 % of the coffee growers located in the community during the study period. The assessed variables included sociodemographic aspects (age, education, ethnicity), characteristics of the agroforestry system (years as a producer, coffee varieties) and technical management variables (soil conservation, training).

Structure and composition of the agroforestry system

The analysis was conducted in 35 production units (16 in *Pascala del Oro* and 19 in *Arroyo Cumiapa*) selected using guided routes along an altitudinal gradient of 500 to 1 000 m, based on the following inclusion criteria: location within the area of influence, producer consent, and active production. The vegetation inventory was carried out using the transect method (Jiménez-González et al., 2023), complemented by *in situ* interviews regarding the use and functional role of the species.

The classification of the agroforestry systems was based on the work of Celi-Delgado and Aguirre-Mendoza (2022). The process was divided into structural and functional determination. The former analyzed the composition and organization using the variables of useful species (inventory and counting of individuals) and spatial arrangement (dispersed patterns, rows, triangular plantings, or living fences). The second step identified the purpose of the species in terms of productive function (food, firewood, timber), protective function (shade, soil conservation), or multifunctionality. For the analysis, species with multiple uses were recorded in all corresponding functional categories based on the priorities declared by the producer. The data were validated by correlating the interview with direct field observation.

The classification of agroforestry systems (AFS) was associated with coffee cultivation (tree and herbaceous components) according to Ramírez and Calvo (2003), grouping the species into four functional categories: nitrogen-fixing, fruit-bearing, timber, and other crops (*e. g.*, ginger and vegetables). Multifunctional species were assigned to their primary function according to the producer's predominant use. The botanical nomenclature was validated using the Plants of the World Online (Powo, 2024) database.

The diversity of tree and herbaceous species in the plots was calculated using the Shannon-Wiener (H') and Simpson ($1–D$) indexes (Magurran, 2004).

The Shannon-Wiener diversity index (*H'*) was determined to quantify evenness and biological richness using the following equation (Shannon, 1948):

$$H' = -\Sigma_{i=1}^{S} piln(pi) \qquad (1)$$

Where:

H' = Shannon-Wiener diversity index

S = Total number of species present (species richness)

pi = Proportion of individuals of species *i* with respect to the total number of individuals in the sample $\left(\frac{ni}{N}\right)$

ln = Natural logarithm

Species diversity was measured using Simpson's (*1–D*) index, which indicates the probability that two randomly selected individuals in a community belong to different species (Simpson, 1949). This was calculated using the following formula (Magurran, 2004):

$$1 - D = 1 - \left[\frac{\Sigma n_i(n_i - 1)}{N(N-1)}\right] \qquad (2)$$

Where:

1–D = Simpson diversity index

ni = Number of individuals of the *i* species

N = Total number of individuals recorded in the sample

Results analysis

The questionnaire data were processed using contingency tables and frequencies. To determine significant associations between communities and qualitative variables, Fisher's Exact Test was applied using R software version 4.2.3 (R Core Team, 2023). The diversity indices, whose analytical basis for quantifying biodiversity has been widely validated, were analyzed.

Results

Sociodemographic characterization

The data in Table 1 show significant differences in the sociodemographic profile of the producers. While both communities share a trend toward the feminization of coffee farming, their structural characteristics differ. Coffee growers in *Pascala del Oro* are predominantly young, have higher levels of education, and their native language is *Me'pha*a (*Tlapaneco*). In contrast, in *Arroyo Cumiapa*, middle-aged producers predominate, with an educational profile limited to basic primary education or low schooling, and linguistically belonging to *Tu'un Savi* (*Mixteco*).

Table 1. Sociodemographic indicators and comparative analysis of coffee producers in *Pascala del Oro* and *Arroyo Cumiapa*.

Indicator	***Pascala del Oro***	***Arroyo Cumiapa***	**Significance (*p*-value)**
Gender	52 % M 48 % W	42 % M 58 % W	p=0.4664 (NS)
Average age	41.3 years	45.5 years	p>0.05 (NS)
Age range	36 % (18-30 years)	60 % (31-50 years)	---
Education level	35 % high school 12 % university	46 % basic 12 % without education	p=0.0344 (*)
Indigenous language	64 % *Me'phaa*	100 % *Tu'un Savi*	---
Ethnicity	*Tlapaneco*	*Mixteco*	---

M = Men, W = Women. NS= Non Significant (p>0.05); (*)= Significant difference (p<0.05).

Background and management of AFS

The results of the structured interviews reveal marked differences in the management and knowledge of AFS (Table 2). On the one hand, in *Pascala del Oro*, the recognition and practice of the system is predominantly based on hereditary transmission. On the other hand, in *Arroyo Cumiapa*, a greater association with government programs was identified; there, half of the producers formally acknowledge the beginning and end of the AFS establishment process as a result of receiving social support. Despite these differences in origin, family income is the main economic driver in both communities.

Table 2. Comparative analysis of management, experience, and motivation in coffee AFS in *Pascala del Oro* and *Arroyo Cumiapa*.

Analysis variable	*Pascala del Oro*	*Arroyo Cumiapa*	Significance (*p*-value)
Knowledge management	92 % appropriation. Hereditary (family) transmission	60 % appropriation. Transmission through peer exchange	p=0.0061 (significant)
Experience (years)	Young/intermediate profile: 40 % have been in operation for 6-10 years	Consolidated profile: 42 % are between 16-20 years old	p=0.0023 (significant)
Reason for starting	16 % due to the market (grain price). Greater autonomy	28 % due to managing social support and subsidies	p=0.0012 (significant)

Technical management of the coffee plantation

The evaluated systems presented contrasting agronomic management practices (Table 3). *Pascala del Oro* is characterized by a greater diversity of varieties (including resistant materials such as *Marsellesa* and *Oro Azteca*), self-management of seedlings in their own nurseries, the implementation of soil conservation works (barriers and contour lines), and the receipt of regular technical advice; likewise, its producers apply chemical control and mixed fertilization combined with systematic pruning.

Table 3. Comparative analysis of technical management and sustainability factors in coffee agroforestry systems between *Pascala del Oro* and *Arroyo Cumiapa*.

Management variables	*Pascala de Oro*	*Arroyo Cumiapa*
Seedling production	High self-managemen (96 %) in their own nurseries	Low production (56 %); 40 % depends on donations from the year 2000
Soil conservation	100 % carry out infrastructure work (60 % barriers, 32 % contour lines)	92 % do not carry out infrastructure work. Only 8 % use barriers
Weed control	100 % manual (*machete* and hoe)	100 % manual (*machete* and hoe)
Fertilization	Chemical (40 %) and mixed (40 %). Only 16 % organic	Organic (34 %); 30 % do not fertilize
Phytosanitary control	80 % chemical; 16 % ecological-traps	54 % chemical; 26 % do not perform control
Pruning practices	80 % perform pruning (64 % maintenance, 16 % sanitation)	42 % do not perform pruning. Only 30 % maintenance
Technical assistance	72 % have regular advice	58 % do not receive professional support

Conversely, in *Arroyo Cumiapa*, the *Typica* variety predominates, and the coffee plantation shows signs of aging due to dependence on plants donated two decades ago. In this latter location, soil conservation practices are not implemented, fertilization and pruning are scarce, and pest control is limited. The only technical similarity between the two communities is weed control, which is carried out traditionally using *machetes* and hoes.

Structure and biodiversity

The predominant model in the region is the rustic mountain system, in which coffee is established under native vegetation enriched with species of economic interest (Table 4 and 5). Given that the descriptive analysis showed a high homogeneity in the structural components of the agroforestry system among the evaluated locations, the results were grouped into the Table 5. At the regional level, eight types of agroforestry associations were identified, among which the mixture of fruit trees, timber trees, and other crops stands out. In addition to providing shade, these species supply firewood, building materials, and food for the *Me'phaa* and *Tu'un Savi* families (Table 6). Spatially, the dispersed arrangement predominates for native species, while the row arrangement is more common for coffee and fruit trees.

Table 4. Comparative analysis of the structure and biodiversity of the coffee agroforestry system between *Pascala del Oro* and *Arroyo Cumiapa*.

Indicator	*Pascala de Oro*	*Arroyo Cumiapa*
Model	Rustic mountain system	Rustic mountain system
Spatial arrangement:		
Dispersed	Native species: pine, oak, fruit trees	Native species: pine, oak, cedar, oak, fruit trees, coffee
Rows	Coffee, fruit trees, timber trees such as cedar	Coffee, fruit trees, timber such as cedar and oak
Triple planting	Coffee and fruit trees	Coffee
Living fences	Oak and cedars	Oak, cedar, pipe tree
Coffee varieties	High diversity (12 varieties). Includes hardy varieties (*Marsellesa*, *Oro Azteca*)	Low diversity (6 varieties). *Typica* variety is predominant
Shannon-Wiener index	2.13	2.27
Simpson index	0.86	0.87

Source: Prepared by the authors using data collected in the field.

Table 5. Predominant associations of coffee agroforestry systems in *Pascala del Oro* and *Arroyo Cumiapa*.

No.	Type of agroforestry system with coffee	Amount	Relative frequency (%)
1	Nitrogen-fixing+fruittrees+timber trees	7	21
2	Nitrogen-fixing+fruit trees+timber trees+other crops	5	15
3	Nitrogen-fixing+fruit trees	1	3
4	Nitrogen-fixing+timber trees+other crops	1	3
5	Fruit trees+timber trees	3	9
6	Fruit trees+timber trees+other crops	11	32
7	Timber trees	2	6
8	Timber trees+other crops	4	12
	Total	34	100

Source: Prepared by the authors using data collected in the field.

Table 6. Uses that producers give to the species associated with coffee agroforestry systems in *Pascala del Oro* and *Arroyo Cumiapa*.

Species	Productive function	Protective function
Avocado (*Persea americana* Mill.)	Food and firewood	Shade for the coffee plantation
Colorín (*Erythrina americana* Mill.)	Firewood	Shade for the coffee plantation, living fence
Cacao (*Theobroma cacao* L.)	Food	Shade for the coffee plantation, soil conservation
Cedar (*Cedrela odorata* L.)	Timber	Shade for the coffee plantation, soil conservation
Oak (*Quercus* spp.)	Timber and firewood	Shade for the coffee plantation
Guajinicuil (*Inga* spp.)	Food and firewood	Shade for the coffee plantation, soil conservation
Guanabano (*Annona muricata* L.)	Food	Shade for the coffee plantation
Lemon (*Citrus×limon* (L.) Osbeck)	Food and firewood	
Mango (*Mangifera* sp.)	Food and firewood	Shade for the coffee plantation, living fence
Nanche (*Byrsonima crassifolia* (L.) Kunth)	Food and firewood	Living fence
Orange (*Citrus×sinensis* (L.) Osbeck)	Food	
Parota (*Enterolobium cyclocarpum* (Jacq.) Griseb.)	Timber	Shade for the coffee plantation, soil conservation
Pine (*Pinus* spp.)	Timber, resin as fuel	Shade for the coffee plantation
Banana (*Musa* spp.)	Food	Shade for the coffee plantation
Pink oak (*Tabebuia rosea* (Bertol.) DC.)	Timber, firewood	Shade for the coffee plantation, living fence
Grapefruit (*Citrus×paradisi* Macfad.)	Food	

Source: Prepared by the authors using data collected in the field.

There is a marked difference in the genetic composition of the main crop between communities. *Pascala del Oro* has high diversity with 12 varieties, integrating traditional materials (*Typica*, Bourbon) with resistant modern germplasm such as *Marsellesa* and *Oro Azteca*. In contrast, *Arroyo Cumiapa* has a lower frequency, with only six varieties, where the *Typica* (creole) variety predominates. This heterogeneity reflects a strategy by producers to balance cup quality with disease resistance, maintaining a larger base of traditional cultivars than in other technologically advanced regions.

The systems in both communities exhibit moderate to high diversity with intermediate structural complexity, regulated by canopy management practices. The Shannon-Wiener index values (2.13 and 2.27) support a medium richness, while the Simpson diversity index (0.86 and 0.87) suggests a high probability of finding different species in the overall sampling. However, the upper canopy exhibits a marked concentration of abundance in a small number of taxa: oak (*Quercus* spp.) leads with 20 %, followed by pine (19 %), rose oak (14 %), and banana (15 %), the latter being an introduced exotic species cultivated for subsistence purposes. This distribution of abundances demonstrates how human management shapes the canopy's physiognomy through the concerted selection of key species.

Discussion

The feminization observed in the management of coffee agroforestry systems in *San Luis Acatlán* is attributed to male migration and multiple employment, a phenomenon of restructuring rural family labor that coincides with the findings of Hernández-Espíndola et al. (2025). However, the heterogeneity of this process is evident when contrasted with regions where male management still prevails (Flores-López & Solís-

López, 2025), demonstrating that gender transfer responds differently to local socioeconomic dynamics.

Furthermore, the population evaluated is notably younger than the national average described by Juárez-Sánchez et al. (2024), suggesting an active generational shift, especially in *Pascala del Oro*. In this latter community, the better conditions for formal education facilitated by its community organization (Carranza-Aburto et al., 2018) contrast with the educational lag in *Arroyo Cumiapa*, a common structural limitation in various Indigenous areas of the country (García-Domínguez et al., 2021).

The correspondence between the *Me'pha*a and *Tu'un Savi* identities and rustic agroforestry systems is not automatic, but rather the result of historical processes of territorial adaptation. These shaded systems are highly adaptable because they mimic the physiognomy of the native forest and allow for the integration of commercial crops without disrupting traditional practices (Aguirre-Cadena et al., 2012). Thus, they operate as scenarios of biocultural continuity through two mechanisms: the safeguarding of taxa of high ethnobotanical value and the hereditary transmission of plots that keeps the native language alive in agricultural work.

This assimilation of polyculture and multi-strata management as extensions of Mesoamerican agriculture (Illescas-Alonso et al., 2020) coexists, however, with contemporary institutional transfer mechanisms, as occurs in *Arroyo Cumiapa*, where the origin of the agroforestry system is directly linked to historical government programs (Valencia et al., 2015). Although family income is the regional economic engine, the disinterest of new generations in the physical effort and low profitability (Higuera-Ciapara & Rivera-Ramírez, 2018), coupled with dependence on subsidies, jeopardizes the long-term sustainability of these systems.

Technical management reveals a sustainability gap between localities. *Pascala del Oro* exhibits superior sustainable indicators through self-management of nurseries and soil conservation (Aguirre-Cadena et al., 2012), while *Arroyo Cumiapa* presents a productive decline characterized by aging coffee plantations and operational neglect, similar to the critical scenario recorded in the state of *Chiapas* by Vázquez-López et al. (2022).

In operational terms, 100 % manual weed control in both communities effectively protects the soil's organic layer (Oropeza-Guevara et al., 2023). Regarding nutrition and health, the coexistence of chemical and organic fertilization to balance yield is observed (García-Zavaleta et al., 2025), along with a transition towards chemical phytosanitary control in *Pascala del Oro* against pests with high economic impact such as the coffee berry borer (*Hypothenemus hampei* Ferrari), *ojo de gallo* (*Mycena citricolor* (Berk. & M. A. Curtis) Sacc., 1887) and anthracnose (*Colletotrichum* spp.) (Tomas-Torres et al., 2018). The absence of shade regulation pruning in 26 % of the producers of *Arroyo Cumiapa* increases the risk of regional epiphytotic, which highlights the limitations of coverage of current agricultural policies compared to comprehensive technology transfer schemes such as the *Sembrando Vida* (Sowing Life) program in *Pascala del Oro* (Pérez-Fernández et al., 2023).

The rustic mountain model functions as a traditional polyculture where canopy planning is not random; multipurpose associations of timber and fruit trees ensure family food and energy sovereignty in the face of market volatility (Silva-Aparicio et al., 2024). Unlike commercial mono-varietal regions (Vázquez-López et al., 2022), *San Luis Acatlán* maintains a heterogeneous genetic base that integrates traditional cultivars (*Typica*, Bourbon) with resistant germplasm (*Marsellesa*, *Oro Azteca*). From an ethnoecological perspective, this multivarietality reflects the complex *Kosmos-Corpus-Praxis*, in which diversification is a culturally ingrained strategy for resistance and risk mitigation that strengthens the territory's resilience (Boege, 2008; Toledo & Barrera-Bassols, 2008).

Structurally, the spatial arrangement denotes a technical transition: the dispersed design predominates in mature plots, while the row design characterizes young plantations, reflecting a linear and gradual adoption of innovations compared to highly technified regions (Benítez-García et al., 2015).

Finally, when reviewing some studies of structure and composition in pine and oak forests, Shannon diversity indexes fluctuate between 1.1 and 2.4, with Simpson dominance between 0.2 and 0.3 (Caballero-Cruz et al., 2022; Castellanos-Bolaños et al., 2010; Ruiz-González et al., 2022). These ecological references allow us to affirm that in the coffee-growing agroforestry systems of *San Luis Acatlán*, the diversity is similar to that of the area's natural forests, but with a marked effect induced by human management, manifested in the high dominance of some species.

Confirming the diversity results in the studied coffee-growing agroforestry systems, other authors consider that values less than 1 for the Shannon index represent low diversity for this type of temperate forest (Méndez-Osorio et al., 2018); therefore, *H'* values >2 can be considered moderate to high in pine-oak ecosystems.

Conclusions

The coffee agroforestry systems in *San Luis Acatlán*, *Guerrero*, are characterized as rustic mountain systems that harbor levels of biological diversity equivalent to those of the region's native forests. The canopy of these systems, dominated by native genera such as *Quercus* and *Pinus*, is actively shaped by human management to fulfill multifunctional purposes of shade, energy, and self-sufficiency.

At a socio-ecological level, local coffee farming does not follow a homogeneous dynamic, but is strongly influenced by the forms of community organization and ethnic identity of each locality. Thus, while the *Me'phaa* community (*Pascala del Oro*) exhibits a highly sustainable model characterized by active generational succession, self-management of resistant germplasm, and rigorous soil conservation practices; the *Tu'un Savi* community (*Arroyo Cumiapa*) shows a marked operational vulnerability exhibited in the aging of its plantations and dependence on external subsidies.

Finally, it is concluded that the long-term structural stability of these biocultural refuges depends on resolving local technical asymmetries, where the system's viability hinges on the capacity to activate generational succession and implement comprehensive phytosanitary management that safeguards agrobiodiversity.

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Conflict of interest

The authors declare no conflict of interest.

Contribution by author

María del Rosario Torralba Ponce: fieldwork and drafting of the first version of the manuscript; Sergio Martínez Trinidad: research direction and manuscript review; Angel Bustamante González: data analysis; Martín Neri Suárez: manuscript review.

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