Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Article

The coffee agroecosystem: traditional polyculture *versus* commercial polyculture in Chocamán, Veracruz

Arturo Pérez-Vázquez[1]
Olivia Pérez-Sánchez[1,§]
Verónica Lango-Reynoso[1]
Esteban Escamilla-Prado[2]

1 Campus Veracruz-Colegio de Postgraduados. Carretera federal Xalapa-Veracruz km 88.5, Tepetates, Manlio Fabio Altamirano, Veracruz, México. CP. 91690. Tel. 229 2010770. (parturo@colpos.mx).

2 Universidad Autónoma Chapingo-CRUO. Carretera Huatusco-Xalapa km 6, Huatusco, Veracruz. CP. 94100. (espreschoca@yahoo.com.mx).

Autora para correspondencia: ia-olivia.ps@hotmail.com

Abstract

Coffee cultivation has strong social and historical-cultural roots in the mountainous area of the state of Veracruz. Its ancestral cultivation was carried out in agroforestry systems, the original pattern of which has been modified. The association of coffee with cash crops is conceived as an option to address its low profitability. Therefore, the objective was to compare the level of sustainability of traditional polyculture coffee *versus* commercial polyculture coffee in three communities in Chocamán, Veracruz during 2021. A survey and a sampling were carried out to estimate plant and soil biodiversity; a physical-chemical analysis of the soil was also performed. Regarding the environmental aspect, organic matter had a higher percentage in commercial polyculture coffee. In the economic dimension, commercial polyculture coffee was 50% more profitable compared to traditional polyculture coffee. On the social side, there were differences in schooling, age of producers, off-farm activities, level of organization and type of agriculture. It was concluded that commercial polyculture coffee had better economic indicators, while traditional polyculture coffee achieved better environmental and social indicators.

Keywords:

agroforestry systems, biodiversity, soil quality, sustainability.

Revista Mexicana de Ciencias Agrícolas
REMEXCA
DOI: https://doi.org/10.29312/remexca.v15i2.3248

Introduction

Coffee production in Mexico is important due to the cultivated area and the population involved (Secretaría de Agricultura, 2023), in addition to contributing to the socioeconomic and environmental components in coffee-growing areas (Manson *et al*., 2008; Pronti and Coccia, 2021). It is grown in shade and traditional polyculture systems (Moguel and Toledo, 1999). However, traditional production systems in the state of Veracruz, Mexico, are modified as commercial or specialized polyculture in order to be more profitable, reduce damage due to diseases, pests, and international prices, and adopt intensive production models (Henderson, 2019; Cerda *et al*., 2020).

The state of Veracruz has produced coffee since the late eighteenth century (Ejea, 2009), ranking second nationally with 24.7% of production, Olguín *et al*. (2011); Cruz-Aguilar *et al*. (2014); CEDRSSA (2019) reported that commercial polyculture in Tlapacoyan, Veracruz, is more productive than monocultures, and labor productivity exceeds opportunity cost.

Traditional shade-grown coffee systems provide ecosystem benefits and services (Beer *et al*., 2004; Komar, 2006; De Beenhouwer *et al*., 2013). In addition, certification initiatives, such as sustainable coffee or rainforest, include shade trees as an environmental indicator (Bravo-Monroy *et al*., 2016).

Coffee systems are distinguished in terms of shade type into rustic, traditional polyculture, commercial polyculture, specialized shade, and full sun monoculture (Moguel and Toledo, 1999; Escamilla-Prado and Díaz-Cárdenas, 2016). Research contrasting traditional polyculture coffee with commercial polyculture coffee in Veracruz is scarce.

Therefore, the objective was to compare the level of sustainability of traditional polyculture coffee (TPC) *versus* commercial polyculture coffee (CPC) in the municipality of Chocamán, Veracruz. Under the hypothesis that the TPC presents higher levels of sustainability compared to the CPC.

Materials and methods

Tetla, Chocamán, and San José Neria belong to the municipality of Chocamán, geographically located in the center of the state of Veracruz (18° 58’ and 19° 02’ north latitude; 97° 00’ and 97° 06’ west longitude) at altitudes of 1 100 to 2 200 m (SIM, 2019), a region that occupies a total area of 44.4 km^2 (Figure 1).

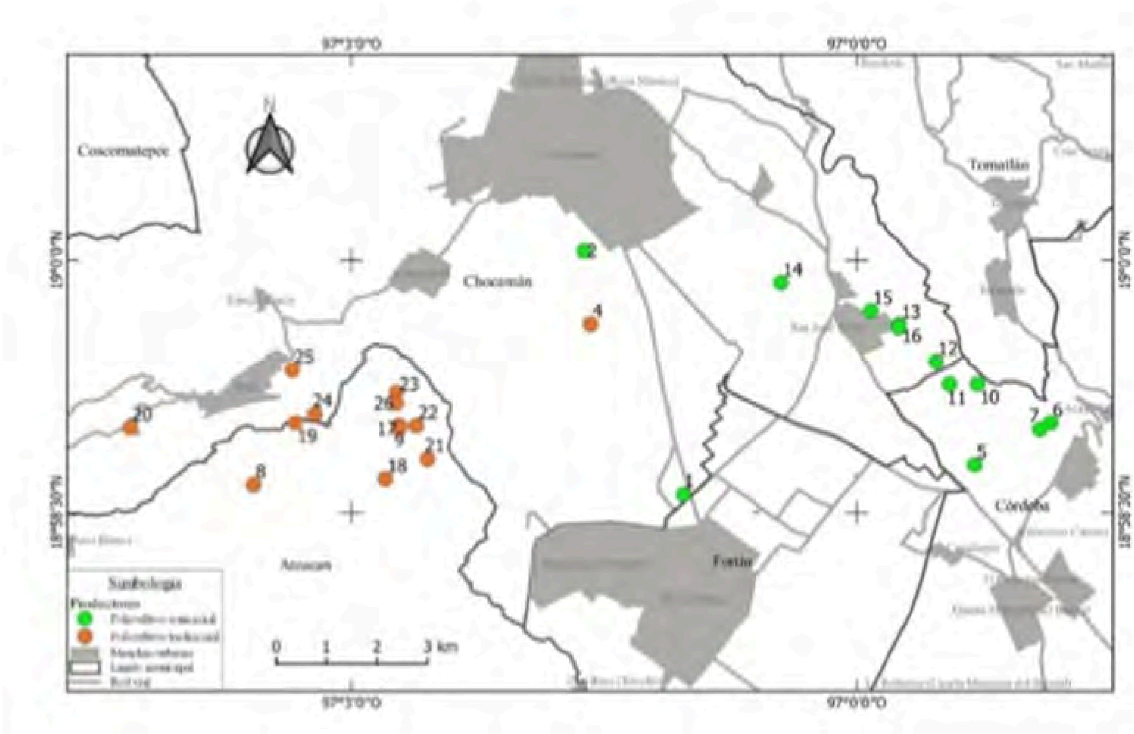
Revista Mexicana de Ciencias Agrícolas
DOI: https://doi.org/10.29312/remexca.v15i2.3248

Figure 1. Geographic location of the localities of Tetla, Chocamán, and San José Neria in Chocamán, Veracruz, Mexico.

The research was descriptive and comparative to characterize production systems based on socioeconomic and environmental indicators. The methodology was adapted from (Sarandón and Flores, 2009). The sample size, determined based on plot and time availability, was 26 coffee plots in the communities under study, of which 13 corresponded to the TPC system and 13 to the CPC system (Figure 2). The selection of the plots was adjusted to the typology indicated by Escamilla-Prado and Diaz-Cárdenas (2016).

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Figure 2. Geographic location of coffee plantations in the municipality of Chocamán, Veracruz, Mexico.



A structured questionnaire was designed to collect economic, social, and technological information from the systems (Kvale and Brinkmann, 2009), with six sections: producer and farm profile, agronomic management, economic and technological component, and level of acceptance. Developed social, economic, and environmental indicators were used to measure multidimensional sustainability.

Each dimension and variable were weighted, with each variable including 12 indicators. Biodiversity measurement was carried out with simple random sampling (Mostacedo and Fredericksen, 2000) using the quadrant method (two per plot). Quadrants of 10 m x 10 m per farm were randomly placed, and the following was measured: density, cover, and frequency of plants (trees, shrubs, herbaceous plants), height, and diameter at breast height (DBH) of tree species.

Quadrants were randomly selected from a total of 10 located in each plot. Coffee planting density, variety, age, and percentage of replanting were estimated. In CPC, banana plants, height, DBH, and variety were counted. Leaf litter was collected in the same quadrant. Two pits measuring 20 cm long x 20 cm wide x 20 cm deep were made per plot, which were randomly placed.

Likewise, in the 10 m x 10 m quadrant, a diagonal line was drawn from north to south, and the 0.50 x 0.50 cm frame was thrown to locate the sampling points. The monoliths were separated into two layers of depth (0-10, 10-20). Using entomological tweezers, organisms larger than 2 mm in size were extracted for taxonomic identification up to order, weighed and counted. The organisms were stored in vials with 150 ml of ethyl alcohol (96°).

Chemical analyses of the soil were total organic carbon, pH, electrical conductivity, nitrogen, phosphorus, potassium, organic matter, and soil type. Descriptive statistical analysis, multiple correspondence analysis for each dimension of the study, and non-hierarchical cluster analysis were performed using the SPSS program.

Revista Mexicana de Ciencias Agrícolas
REMEXCA
DOI: https://doi.org/10.29312/remexca.v15i2.3248

Results and discussion

Producer profile

In the TPC, the average age of the producers was 64 years, with 35 years of experience in cultivation. In terms of schooling, 31% are illiterate, and 54% have elementary education. Among the landowners, 15% are ejidatarias (female shareholders of communal land). The average annual income per producer is $25 550.00 MXN, with an average yield of 2.15 t ha^{-1} of cherry coffee and a sale price of $7.00 to $8.00 MXN kg^{-1} (2019-2020 cycle). To supplement their income, 38% are engaged in off-farm activities or grow an alternative crop.

In some cases, they associate coffee with myrtle (*Myrtus communis* L.) and orange jasmine (*Murraya paniculata*). In addition, they have income from the sale of firewood, ground coffee, and crops such as tabaquero chili (*Capsicum* spp.) and serrano chili (*Capsicum* spp.). Family labor is common, with nuclei of five members on average.

In the CPC, the average age of the producers was 58 years old, with 31 years of experience in cultivation. Thirty-eight percent studied the elementary level and 23% university and postgraduate levels. The ejidatarias represent 7% of the landowners. The average annual income from coffee sales is $54 769.23 MXN, with average yields of 4 t ha^{-1} (2019-2020 cycle). Unlike TPC, cash crops have high planting densities and represent 60% of annual household income.

For example, banana (*Musa* spp.) leaves and macadamia (*Macadamia* spp.) are crops associated with coffee plantations. In addition, crops such as sugarcane (*Saccharum officinarum*) and chayote (*Sechium edule*) contribute to the producer’s economy. The use of family labor is lower compared to the TPC. Off-farm activities are a key factor in both systems. In the case of the TPC, 46% of income is from off-farm activities, compared to the CPC, where they contribute up to 84% (Table 1).

Table 1. Characteristics of traditional polyculture coffee (TPC) producers *versus* commercial polyculture coffee (CPC) producers.

Variable	TPC*	CPC*
Age of the producer	Average: 64 (46-85)	Average: 58 (44-68)
Maximum level of schooling	University 23% Elementary school, 54%	University 15% Elementary school 38%
Gender	15% women, 85% men	8% women; 92% men
Average time as coffee producer	35 years (3-70)	31 years (6-54)
Average years associating a cash crop*	11 (7-20)	21 (5-40)
Average income from cherry coffee sales	$ 23 05.697	$ 64 969.23
Off-farm activities	38% with activity 62% without activity	69% with activity 31% without activity
Average size of the family	5 (2-11)	4 (2-8)

* = 2019-2020 cycle.

Typology of production system

TPC was predominant in Tetla and absent in San José Nería. Based on the altitudinal strata, Tetla is located at a higher altitude, where 92% of the producers grow an average of 1.6 ha of coffee, with a predominance of ejido tenure (77%). The traditional tall varieties of *C. arabica* cultivated are: Bourbon, Criollo or Typica, Caturra, and Garnica, but due to rust, they were replaced by varieties such as Colombia, Costa Rica, Marseillaise, Oro Azteca, Geisha, and Questlansase.

The latter two with excellent quality potential and tolerance to rust, productive, and with good organoleptic quality (Henderson, 2019). However, they are varieties adapted to intensive management. The process of renovating traditional coffee plantations began 10 years ago on 15% of the farms. By the year 2020, on average, 40% of TPC farms had been renovated.

DOI: https://doi.org/10.29312/remexca.v15i2.3248

In terms of management, 7.6% is certified organic (CERTIMEX agency), and 92.4% is conventional. The TPC produced an average of 1.93 t ha^{-1} of cherry coffee (2019-2020), with records of 1.9 t ha^{-1} to 2.89 t ha^{-1}. The CPC was located mainly in San José Neria (76%) and partially in Chocamán. Farm areas of 1 ha predominate in 39.5%, and the ejido predominates in 92.3% as land tenure.

The varieties grown are: Typica or Criollo, Bourbon, Caturra, and Garnica. The dominant varieties are Colombia, Costa Rica, Geisha, and Marseillaise, with conventional management (84.6%) and an average production of 4.79 t ha^{-1} (2019-2020 cycle). Coffee plantations have been renovated in 70%, where the Humic Andosol (Th) loamy soil predominates (Table 2).

Table 2. Characteristics and differences between the traditional polyculture coffee (TPC) system *versus* the commercial polyculture coffee (CPC) system.

Characteristics	TPC	CPC
Area cultivated with coffee	Average: 1. 62 ha (0.5-6.5)*	Average: 1.63 (1.0-2.75)
Land tenure	Ejido, 77%, private, 23%	Ejido, 92.3%, private, 7.6%
Common varieties in old plantations	Bourbon, Criollo, Caturra, and Garnica	Criollo, Bourbon, Caturra, and Garnica
Varieties currently grown	Colombia, Costa Rica, Marseillaise, Geisha, Questlansase, and Oro Azteca	Colombia, Costa Rica, Geisha, and Marseillaise.
Density of coffee plants ha^{-1}	Average: 3 219 (2 400-4 500)	Average: 3 553 (2 500-6 400)
Age of renewed coffee plants	Average: 4 years (1-10)	Average: 5 years (3-10)
Average percentage of renewed coffee plantation	41	70
Average percentage of organic coffee	7.6	15.3
Average percentage of conventional coffee	92.3	84.6
Minimum yield	1.911 t ha^{-1}	1.125 t ha^{-1}
Maximum production	2.89 t ha^{-1}	5.94 t ha^{-1}
Predominant type of management	Conventional	Conventional

* = minimum and maximum values in parentheses.

Agro-environmental characteristics

Chocamán has 9 738 inhabitants, of which 28% (420 families) are engaged in coffee cultivation, cattle farming, and agribusiness. Tetla, with its very steep terrain, has 2 379 inhabitants, of which 38% (128 families) are engaged in coffee growing. San José Neria is home to 1 522 people, 56% of them (190 families) are engaged in coffee, sugarcane, and livestock production (Table 3) (PueblosAmerica.com, 2023).

Table 3. General characteristics of the coffee farms evaluated, in the altitudinal gradient.

Variable	Tetla	Chocamán	San José Neria
Altitude (m)	1 524	1 360	1 210
Climatological classification	Humid temperate	Humid temperate/humid semi-warm temperate	Humid semi-warm temperate
Average slope on coffee farms (%)	26	17	11
Average of shade on coffee farms (%)	59	53	46
Average height of trees (m)	12.33	14.85	10.33
Average DBH of trees (cm)	31.04	24.56	39.1
Type of soil*	Clayey	Loamy	Loamy

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Variable	Tetla	Chocamán	San José Neria
Crops with economic importance	Myrtle, tabaquero chili, orange jasmine, serrano chili, banana leaves	Macadamia, banana leaves	Sugarcane, banana leaves, chayote, macadamia

*Determination in accordance with NOM-021-RECNAT-2000.

Biodiversity and composition of coffee plantations

A total of 80 plant species belonging to 75 genera and 40 families were recorded in the systems. Of particular note are the Solanaceae (8), Fabaceae (7), and Rutaceae (6). The TPC had 72 species, of which 65.5% belong to the tree stratum, 11.1% to the shrub stratum, and 23.6% to the herbaceous stratum. The CPC presented 45 species, with 80% tree stratum, 4.4% shrub stratum, and 15.5%herbaceous stratum. Of the total species, 30 were present in both systems, 37 in TPC and 13 in CPC.

Fruit trees are the main component of the TPC and ornamental plants (*Murraya paniculata* and *Myrtus communis*) with economic value, which represent an additional annual income. In the CPC, they have plants of banana (*Musa acuminata* Colla) for leaves and macadamia (*Macadamia integrifolia* and *M. tetraphylla*). Due to its structure, the TPC obtained the best biodiversity metrics, except for relative abundance, where the CPC stood out for the presence of *Musa acuminata* as an associated cash crop (Table 4).

Table 4. Biodiversity metrics in traditional (TPC) and commercial (CPC) polyculture coffee.

Diversity metrics	TPC	CPC
Richness (no. of species)	72	45
Shannon-Wiener index	2.638	1.443
Relative abundance	1.625	2.6
Equity	0.617	0.379
Dominance	0.496	0.385

Soil quality

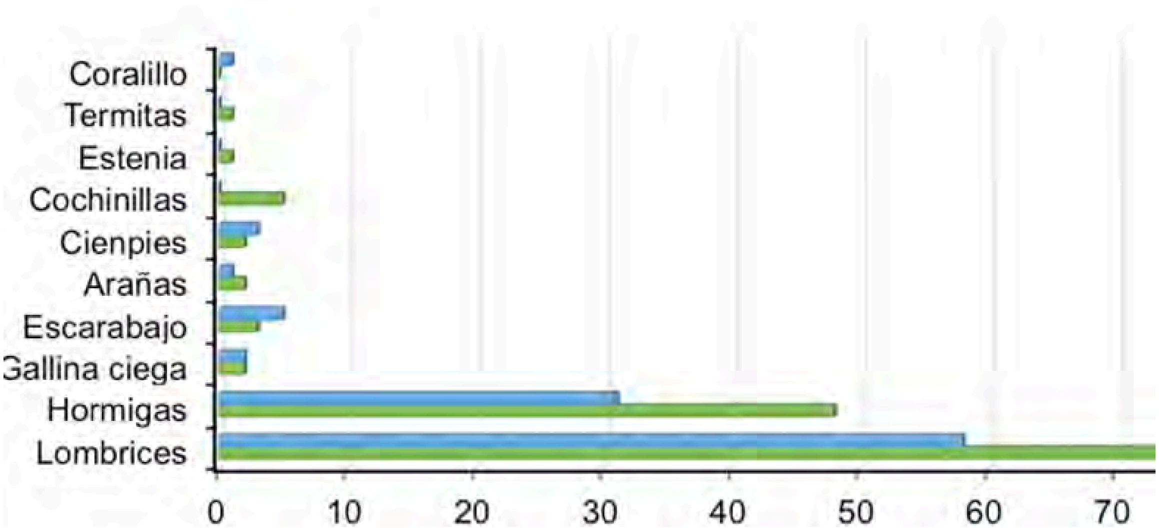
TPC soils had an average pH of 4.98 (acidic), and those of CPC, 5.2 (moderate acidity). When the pH is higher than 5.5, Al^{+3} is neutralized and ceases to be a problem for coffee growth (Sadeghian, 2016). In this case, 53% of the TPC farms reached levels >2 of Al^{+3}, and in CPC, 30% reached levels >2 meq 100 g^{-1} in Al^{+3} content. This indicates levels of Al toxicity (Casierra and Aguilar, 2007).

The average organic matter content was 6.55, with a medium to high range for TPC. The CPC had an average of 5.71%, with a minimum to low range of OM, results consistent with the findings of López-Báez *et al*. (2016). Organic matter in soils comes from leaf litter produced by coffee plants and shade trees (Farfán and Urrego, 2007).

The organic matter values identified indicate that, although temperature and precipitation conditions exist in the region, acidic pH is likely to affect humification and mineralization (Noriega-Altamirano *et al*., 2014). Regarding the epigeal macrofauna, 10 varieties were identified, where ants and earthworms were the most abundant in both systems, with the TPC having the highest number of macroorganisms per sampled area (Figure 3).

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Figure 3. Average number of edaphic fauna individuals present in TPC and CPC.



TPC *vs* CPC profitability

The CPC farm obtained the best income from the sale of coffee products ($75 763.09 MXN), with high production costs ($29 142.77 MXN) and higher profit ($46 620.31 MXN), differing from what was reported by Jezeer *et al*. (2018), where the economic return was similar for shade coffee type (Table 5).

Table 5. Average economic and financial indicators of the TPC and CPC systems.

Indicator	TPC	CPC
Investment cost*	452 570.92	391 953.31
Operating cost*	10 502.46	29 142.77
Total annual income*	38 296.15	75 763.08
Annual profit*	27 793.69	46 620.31
Daily profit*	76.15	127.73
B/C Ratio	0.22	0.53

* = in Mexican pesos (MXN).

Van Asten *et al*. (2011) determined the profitability of associated coffee and banana systems compared to monoculture in *C. arabica* L. and *C. canephora*; they concluded that coffee-banana intercropping is more profitable than banana-coffee monoculture (Table 5). In the TPC, its various products and by-products are not economically valued because they are for self-consumption.

The CPC system income was 49.9% higher than the TPC, and profits were also higher, allowing them to be reinvested. The TPC allocates 27% of its income to its operation, unlike the CPC, where 38% of the income goes to its maintenance and operation. Regarding TPC, it has a lower use of inputs with reduced production costs and family labor at 84%.

Sustainability analysis

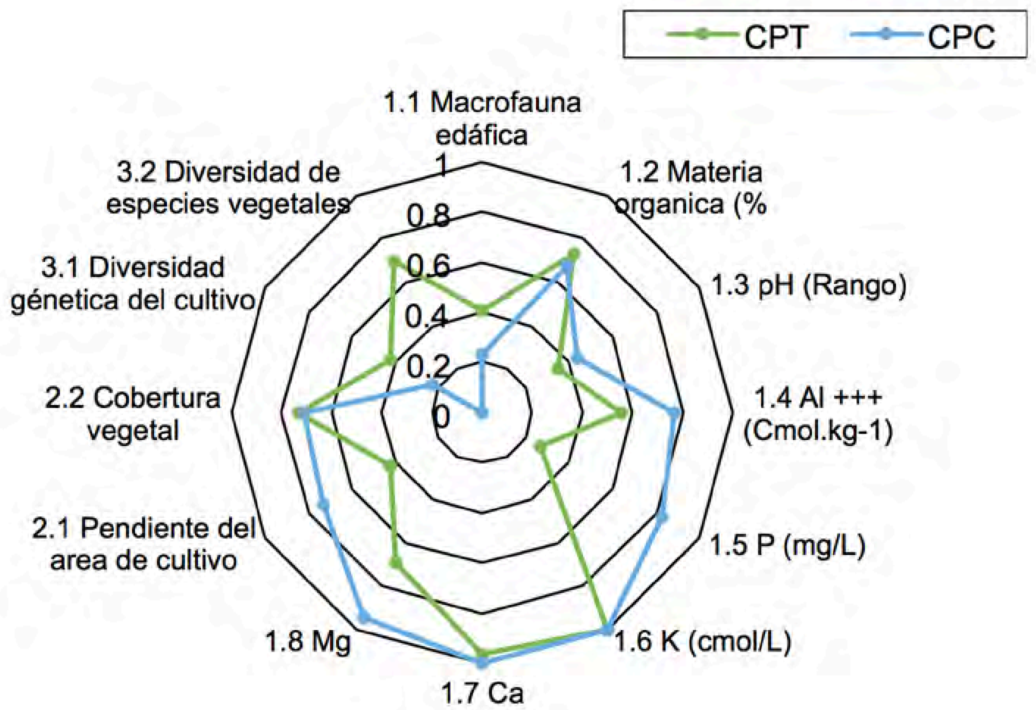
The environmental sustainability of the systems was average in terms of soil quality (0.62 for TPC and 0.73 for CPC). Nutrients and physical and chemical parameters were above average. The

DOI: https://doi.org/10.29312/remexca.v15i2.3248

diversity of edaphic and genetic macrofauna was higher in the TPC. The vegetation cover of the soil was similar; the presence or absence of cover is related to the control of weeds by producers.

The slope of the land is an important factor in water erosion; the TPC has slopes between 10% and 55%, while the CPC has a lower risk of soil loss due to its low slope. Both polycultures had a high density of vegetation and leaf litter, which significantly reduces erosion (Figure 4). The biggest difference between systems was the indicator of plant diversity.

Figure 4. Ecological-environmental sustainability indicators of the traditional polyculture coffee system (green line) *vs* commercial polyculture coffee system (blue line).

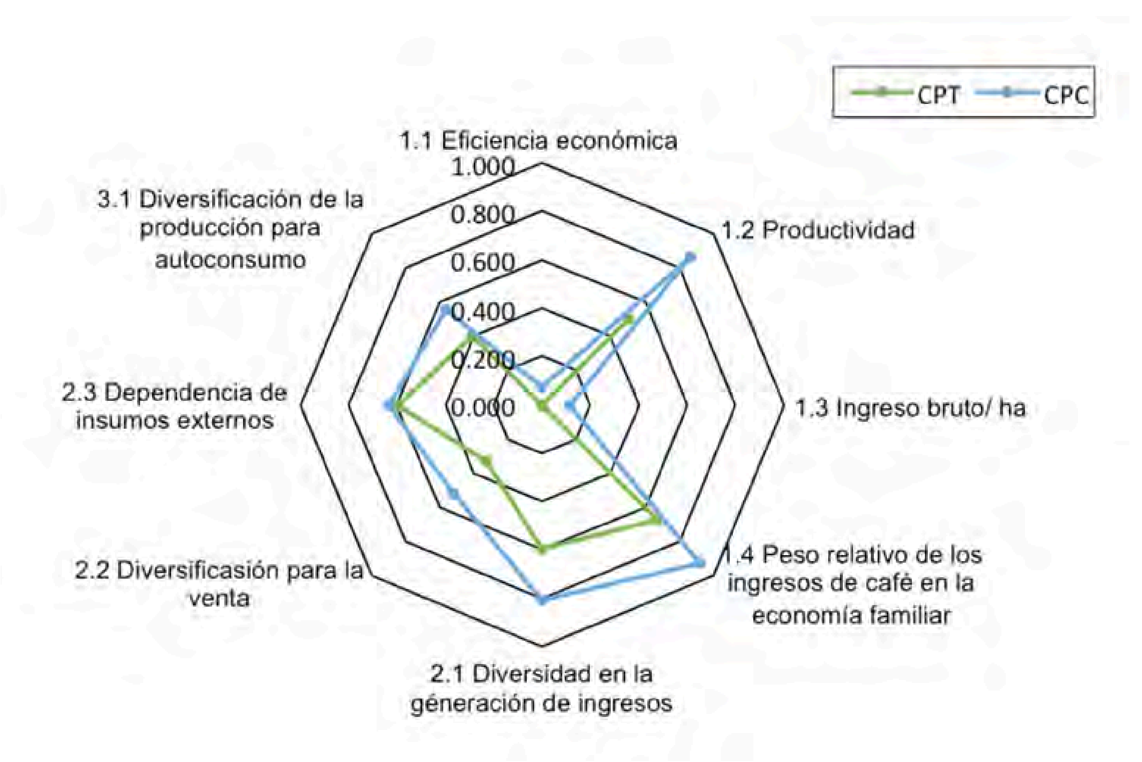


An average economic sustainability was obtained in 92% of the CPC farms and 77% of the TPC farms, with a B/C ratio of less than 1 for TPC and 1.49 for CPC. In the gross income per farm indicator, 100% of TPC presented zero sustainability, and 8% of CPC was highly sustainable.

In terms of diversity in income generation, the TPC had a medium sustainability (0.5), contrary to the CPC with 0.8. Regarding commercial diversification, the TPC had a score of 0.07 since most farms are engaged exclusively in the sale of coffee, unlike the CPC, where 92% obtain at least two products to market. In terms of diversification of production for self-consumption, in TPC, it presented low sustainability since 30% of farms do not diversify for self-consumption, while in CPC, 92% of farms have at least two species of food importance (Figure 5).

Revista Mexicana de Ciencias Agrícolas
REMEXCA
DOI: https://doi.org/10.29312/remexca.v15i2.3248

Figure 5. Indicators of economic sustainability of the traditional polyculture coffee system (green line) *vs* the commercial polyculture coffee system (blue line).



In the social dimension, 85% of the TPC farms had a medium sociocultural sustainability (0.605), as did the CPC (0.592). The TPC coffee system is highly accepted, and with a high willingness to remain in the activity. Similarly, CPC producers reported high acceptance. In terms of cultural tradition, both systems had a high score (0.71 and 0.73). The basic needs satisfaction indicator presented values of 0.2 and 0.3, indicating low satisfaction of basic needs (Figure 6).

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Figure 6. Indicators of socioeconomic sustainability of the traditional polyculture coffee system (green line) *vs* the commercial polyculture coffee system (blue line).

Conclusions

The coffee agroecosystem in traditional polyculture (TPC) differs in structure, management, diversity of plant species, edaphic macrofauna, as well as the use and purpose of the species, with respect to commercial polyculture coffee (CPC). The ecological-environmental differences between TPC and CPC are related to physical, sociocultural, socio-environmental, and edaphoclimatic factors.

In both systems (TPC and CPC), there is great acceptance of coffee cultivation and willingness of producers to remain in the activity due to their attachment to the crop, tradition, and good profits if international coffee prices are high. The TPC and CPC reflect the socio-environmental conditions of coffee production and apply different strategies, based on a logic differentiated by the producer's objectives, and influenced by the level of backwardness, marginalization, education, training, and food security.

Producers with TPC are from peasant agriculture and opt for this system because it allows them to survive, unlike CPC producers who have higher incomes and have a different socioeconomic profile. The TPC presented a higher level of environmental sustainability, while the CPC presented greater economic sustainability. Finally, it is important to promote strategies to improve coffee agroecosystems, so that they are an important source of food, income, and biodiversity conservation. Some of them are their own brand of coffee, and agroforestry systems with priority to include food crops or crops of high commercial value.

DOI: https://doi.org/10.29312/remexca.v15i2.3248

Bibliography

1 Beer, J. M.: Ibrahim, E. J.; Somarriba, A. B. y Leakey, R. 2004. Establecimiento y manejo de árboles en sistemas agroforestales. Árboles de Centroamérica. CATIE. Turrialba, Costa Rica. 197-242 pp.

2 Bravo-Monroy, L.; Potts, S. G. and Tzanopoulos, J. 2016. Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. Food Policy. 58:49-61. doi.org/10.1016/j.foodpol.2015.11.003.

3 Casierra, F. y Aguilar, O. 2007. Estrés por aluminio en las plantas reacciones en el suelo: síntomas en vegetales y posibilidades de corrección. Revista Colombiana de Ciencias Hortícolas. 1(2): 246-256.

4 CEDRSSA. 2019. Centro de estudios para el desarrollo rural sustentable y la soberanía alimentaria. Comercio internacional del café, el caso de México. Palacio Legislativo, San Lázaro. México, DF. 11 p.

5 Cerda, R.; Avelino, J.; Harvey, C. A.; Gary, C.; Tixier, P. and Allinne, C. 2020. Coffee agroforestry systems capable of reducing disease induced yield and economic losses while providing multiple ecosystem services. Crop Protection. 2020https://doi.org/10.1016/j.cropro.2020.105149.

6 Cruz-Aguilar, A. R.; Leos, J. A.; Uribe, R. M. y Rendón, G. R. 2014. Evaluación socioeconómica del sistema agroforestal tradicional café-plátano-cítricos en el municipio de Tlapacoyan, Veracruz, México. Tropical and Subtropical Agroecosystems. 17(2):315-319. https://www.redalyc.org/articulo.oa?

7 De Beenhouwer M.; Aerts, R. and Honnay, O. 2013. A global meta-analysis of the biodiversity and ecosystem service benefits of coffee and cacao agroforestry. Agric. Ecosyst. Environ. 175:1-7. http://dx.doi.org/10.1016/j.agee.2013.05.003.

8 Ejea, M. M. T. 2009. Café y cultura productiva en una región de Veracruz. Nueva Antropología. 22(70):33-56.

9 Escamilla-Prado, E. y Diaz-Cárdenas, S. 2016. Sistemas de cultivo de café en México. SAGARPA-COFUPRO-CENACAFE-UACH. Xalapa. 63 p.

10 Farfán V. F. y Urrego B. J. 2007. Descomposición de la hojarasca y liberación de nutrientes de *Coffea arabica*, *Cordia alliodora*, *Pinus oocarpa* y *Eucalyptus grandis*, en sistemas agroforestales con café. Centro Nacional de Investigaciones de Café (CENICAFÉ). 58(1):20-39.

11 Henderson, T. P. 2019. La roya y el futuro del café en Chiapas. Revista Mexicana de Sociología. 81(2):389-416.

12 Jezeer, R. E.; Santos, M. J.; Boot, R. G.; Junginger, M. and Verweij, P. A. 2018. Effects of shade and input management on economic performance of small-scale *Peruvian* coffee systems. Agricultural Systems. 162:179-190. Doi.org/10.1016/j.agsy.2018. 01.014.

13 Komar, O. 2006. Priority contribution: ecology and conservation of birds in coffee plantations; a critical review. Bird conservation international. 16(1):1-23. Doi: 10.1017/S0959270906000074.

14 Kvale, S. and Brinkmann, S. 2009. InterViews. Learning the craft of qualitative research interviewing. 2$^{nd.}$ Ed. SAGE. Los angeles: sage. 354 p.

15 López-Báez, W.; Castro-Mendoza, I.; Salinas-Cruz, E.; Reynoso-Santos, R. y López-Martínez, J. 2016. Propiedades de los suelos cafetaleros en la reserva de la biósfera el triunfo, Chiapas, México. Revista Mexicana de Ciencias Agrícolas. 7(3):607-618.

16 Manson, R.; Hernández-Ortíz, V.; Gallina, S. y Mehltreter, K. 2008. Agroecosistemas cafetaleros de Veracruz. biodiversidad, manejo y conservación. instituto de ecología. Ed.

DOI: https://doi.org/10.29312/remexca.v15i2.3248

(INECOL) e Instituto Nacional de Ecología (INE-SEMARNAT). Xalapa, Veracruz. México, DF. 348 p.

17 Moguel, P. y Toledo, V. M. 1999. Biodiversity conservation in traditional coffee systems of México. Conservation Biology. 13:11-21. Doi: 10.1046/j.1523-1739.1999.97153.x.

18 Mostacedo, B. B. y Fredericksen, T. S. 2000. Manual de métodos básicos de muestreo y análisis en ecología vegetal. Santa Cruz, Bolivia. Ed. El país. Tipos de muestreo de vegetación. 10-11 pp.

19 Noriega-Altamirano, G. B.; Cárcamo, R. M. A.; Gómez C. R.; Schwentesius, R. S.; Cruz, H. J.; Leyva, B. E.; García. R. U. I.; López, R. A. y Martínez, H. 2014. Intensificación de la producción en la agricultura orgánica: caso café. Revista Mexicana de Ciencias Agrícolas . 5(1):163-169.

20 Olguín, J. E.; Sánchez-Galván, G. y Mercado, G. V. 2011. La producción de café como amenaza a la biodiversidad. *In*: comisión nacional para el conocimiento y uso de la biodiversidad (CONABIO). Gobierno del Estado de Veracruz, Universidad Veracruzana, Inecol AC. 541 p.

21 Pronti, A. and Coccia, M. 2021. Multicriteria analysis of the sustainability performance between agroecological and conventional coffee farms in the east region of minas Gerais (Brazil). Renewable Agriculture and Food Systems. 36(3):299-306. Doi: 10.1017/S1742170520000332.

22 PueblosAmerica.com. 2023. https://mexico.pueblosamerica.com/veracruz-de-ignacio-de-la-llave/chocaman/.

23 Sadeghian, S. 2016. La acidez del suelo, una limitante común para la producción del café. Avances técnicos CENICAFÉ. Manizales, Caldas, Colombia. 12 p.

24 Sarandón, S. J. y Flores, C. C. 2009. Evaluación de la sustentabilidad en agroecosistemas: una propuesta metodológica. Agroecología. 4:19-28. https://revistas.um.es/agroecologia/article/view/117131.

25 SIM. 2019. Sistema de Información Municipal. Cuadernillos Municipales Chocamán. http://ceieg.veracruz.gob.mx. 10 p.

26 Van-Asten, P. J. A.; Wairegi, L. W. I.; Mukasa, D. and Uringi, N. O. 2011. Agronomic and economic benefits of coffee banana intercropping in Uganda's smallholder farming systems. Agricultural Systems . 104(4):326-334. doi.org/10.1016/j.agsy.2010.12.004.

Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v15i2.3248

The coffee agroecosystem: traditional polyculture *versus* commercial polyculture in Chocamán, Veracruz

Journal Information
Journal ID (publisher-id): remexca
Title: Revista mexicana de ciencias agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 01 January 2024
Date accepted: 01 February 2024
Publication date: 08 March 2024
Publication date: March 2024
Volume: 15
Issue: 2
Electronic Location Identifier: e3248
DOI: 10.29312/remexca.v15i2.3248

Categories

Subject: Articles

Keywords:

Keywords:

agroforestry systems

biodiversity

soil quality

sustainability

Counts

Figures: 6

Tables: 5

Equations: 0

References: 26

Pages: 0