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Socio-economic characterization of the traditional cacao agroforestry system (*Theobroma cacao* L.)

Caracterización socioeconómica del sistema tradicional agroforestal de cacao (*Theobroma cacao* L.)

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ARTICLE DATA

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ABSTRACT

Cacao farmers face many challenges to increase yield while adjusting their farms to future environmental and socio-economic uncertainties. Improving the management practices of cacao (*Theobroma cacao* L.) cultivation systems requires knowledge of their baseline and the determining factors affecting them. The main goal of this research was to characterize traditional cacao agroforestry systems of smallholder farmers in the Municipality of Tumaco, Nariño, Colombia. Using a semi-structured survey and a sample of 218 farmers, the socioeconomic characteristics of the cacao production system were analyzed. Multiple correspondence analysis (MCA) and principal component analysis (PCA) grouped and discriminated the cacao growers. The PCA formed five components representing 50.86% of the total variability, while the ACM grouped them into five factors explaining 29.82% of the variability. The cacao cultivation is a traditional activity of smallholder farmers with very low yields. The age of the farmers is over 50 years old, with despicable levels of education; there was no evidence of generational change. The study shows that the traditional cacao production system is not an attractive activity for young people or investors given its marginality and low economic projection. Timely strategies and subsequent early actions will be imperative to face the main environmental, socio-economic, and productive challenges, which will allow the cacao activity to be a source of well-being for cacao growers and the environment in the region.

Keywords: Pacific coast; Tumaco; typification; yield; production systems; Afro-Colombians.

RESUMEN

Los productores de cacao enfrentan muchos desafíos para aumentar el rendimiento mientras ajustan sus fincas a las incertidumbres ambientales y socioeconómicas. Mejorar las prácticas de manejo de los sistemas de cultivo del cacao (*Theobroma cacao* L.) requiere conocer su línea de base y los factores determinantes que los afectan. El objetivo de esta investigación fue caracterizar los sistemas agroforestales de cacao tradicionales de los pequeños agricultores en el municipio de Tumaco, Nariño, Colombia. Utilizando una

encuesta semiestructurada y una muestra de 218 agricultores, se analizaron las características socioeconómicas del sistema productivo de cacao. El análisis de correspondencia múltiple (MCA) y el análisis de componentes principales (PCA) agruparon y discriminaron a los productores de cacao. El PCA formó cinco componentes que representan el 50,86% de la variabilidad total, mientras que el ACM los agrupó en cinco factores que explican el 29,82% de esta. El cultivo del cacao es una actividad tradicional de los pequeños agricultores con rendimientos muy bajos. La edad de los agricultores es superior a los 50 años, con niveles de educación muy bajos, sin evidencia de cambio generacional. El sistema tradicional de producción de cacao no es una actividad atractiva para jóvenes o inversores dada su marginalidad y baja proyección económica. Las estrategias oportunas y las acciones tempranas serán imperativas para enfrentar los principales desafíos ambientales, socioeconómicos y productivos, las cuales permitirán que la actividad cacaotera sea una fuente de bienestar para los productores de cacao y el medio ambiente en la región.

Palabras clave: Costa pacífica; Tumaco; tipificación; productividad; sistemas productivos; Afrocolombianos.

INTRODUCTION

The Cacao tree (*Theobroma cacao* L) is native to South America (Motamayor *et al*. 2002), and produces a fruit with the same name (Hernández, 2013), used for different products, being chocolate the most important one (Kaufman and Justeson, 2007). This tropical agricultural commodity (Asigbaase *et al*., 2021, Schroth *et al*. 2017), is positioned in third place after sugar and coffee in the world market, demanded mainly by American and European companies (Meyers, 2021). There is 1,700,000 ha in America, which generates trade flows of over 900 million dollars (Arevalo-Gardini, 2017). Colombia shares 59,740 tons, in 175,000 ha (FEDECACAO, 2020), of fine aroma cacao (FEDECACAO, 2019).

As a substitute for illicit use crops (UNODC and Acción Social, 2008), for its potential to thrive in marginal soils, and for having good social acceptance and economic profitability, this crop plays an important role in conflict zones of Colombia (Pabón *et al*., 2016). Most of the cacao grows under traditional agroforestry systems composed of native tree species, which retain part of the local structure of the surrounding forests and create a favorable environment for cacao and other companion species (Rice and Greenberg, 2000).

This plant structure allows the system to maintain diversity of species and thus, becoming an alternative for the natural habitats´ loss (Cabral *et al*., 2021), ecosystem services (Schroth *et al*., 2017, Perfecto and Vandermeer, 2008; Martin *et al*., 2020; Aguirre-Forero *et al*., 2020). These characteristics made agroforestry systems a feasible smart agriculture approach (FAO, 2013; Kaczan *et al*., 2013).

In Nariño, cacao farms account for 19,666 ha (DANE, 2016), most of them located in the municipality of Tumaco, where cacao grains have developed excellent flavor and aroma (FEDECACAO, 2019), placing them among the best in the world. For example, in the Exhibition Center of the Puerta de Versalles in Paris, this cacao earned the first prize in 2015 (Bautista, 2019). In Tumaco, cacao crops have more than half a century growing always associated with complex and biodiverse species. That matrix means disorder and ignorance of the cacao farmers for agronomists (Espinosa-Alzate and Rios-Osorio, 2016).

In Tumaco, there are about 2,970 farmers with 20,600 farmers that encompass the 9.76% of the total cacao crops' area in the country (FEDECACAO, 2020). Here, cacao grows in traditional systems, especially in marginal

areas (Büchert, 2008), along with coconut, oil palm, and miscellaneous crops (Espinosa-Alzate and Ríos-Osorio, 2016). Under these conditions, cacao crops yield averages 0.29 ton/ha (Agronet, 2018; Preciado *et al*., 2011), being low compared to the Colombian one of 0.46 ton/ha (FEDECACAO, 2019). However, the yields remain appalling because many farms are old, and cacao growers do not apply intensive cultivation techniques.

Under these facts, the cacao crop is not profitable. However, these systems can turn into sustainable with technological management, but the baseline on cacao production knowledge is still limited (Ramírez *et al*., 2014). Characterization of these production systems will allow us to have the missing knowledge and to understand their rationality and function (Méndez and Gliessman, 2002). Thus, agricultural development strategies can be defined with appropriate interventions (Dixon *et al*., 2001), which in turn could attract the young labor force and avoid establishing new cacao farms elsewhere in the forest zones (Wessel *et al*., 2015).

In Colombia, most research has focused on the development of agronomic studies (Jaimes *et al*., 2011; Londoño *et al*., 2011; Osorio-Solano *et al*., 2012; Posada *et al*., 2010) and search for new cacao clones (Perea *et al*., 2011). However, regarding socioeconomic studies, the literature is limited (Mantilla *et al*., 2000); therefore, the characterization is relevant to guide decisions making to make this crop competitive.

Field trials in cacao districts in Côted'Ivoire show that in farms with 25 to 30-year-old cacao trees, rehabilitation is feasible and profitable (Wessel *et al*., 2015). Good maintenance, integrated pest, and disease control raised the average yield over a four-year period, from around 500 to 700 kg per ha. Additional fertilizer use raised the yield further to 1000 kg per ha from the third year of application onwards (Assiri *et al*., 2012). In some places, large-scale rehabilitation and replanting programs are in progress around the world (Wessel *et al*., 2015).

Cacao technification and the promotion of value chains around agro-industrial activities could be an important alternative for the cacao growers in Tumaco to access new markets, generate greater added value, and consequently, improve their income (Banco de Desarrollo de América Latina, 2018).

Therefore, this research was developed within the project framework called "Study for the improvement of productivity and sensory quality (aroma and flavor) of regional cacao (*Theobroma cacao* L) of the department of Nariño"; being one of the objectives to characterize cacao farms in the municipality of Tumaco, Nariño to know the productive systems, establish the baseline and generate participatory alternatives to raise the income level of the cacao growers.

MATERIALS AND METHODS

Study Area. This research was carried out in the municipality of Tumaco, located in the southwestern of Colombia at the coordinates 1°48′34″ North latitude and 78°45′53″ West longitude, with elevations ranging between 0 and 400 masl, an average temperature of 26.2°C and a precipitation of 2,843mm year^{-1}. Tumaco is made up of 13 townships (non-collective area), 15 community councils, and 15 indigenous reservations (Municipio de Tumaco, 2008).

Traditional production systems. Traditional production systems encompass a matrix of cacao mixed with woody, fruit tree species along with miscellaneous crops such as oil and coconut palms. Besides, cacao growers do hunting, fishing, timbering, and wages' sailing. Therefore, in that matrix, cacao farms are old with low technological management and yield. These farms account approximately for 20 thousand ha (DANE, 2016), with a yield of 2,916.5 tons (FEDECACAO, 2019).

Sampling. Tumaco has almost plain landscapes where cacao farms grow on river meadows, small hills, and humid areas. These features do not have a significant effect on cacao yields (Preciado *et al*., 2011); therefore, a random sampling was carried out (formula 1). This method is simple, practical, and thus, suitable for this region.

$$n \geq \frac{N * S^2}{N\left[\frac{d}{z_{1-\propto/2}}\right]^2 + s^2} \qquad (1)$$

Where, n = sample size, N = population size, Z_1- $\alpha/_2$ = Quantile of the standard normal distribution with a probability less than or equal to 1-α/2 (see Z table), S^2 = Variance of the estimated population, d = Maximum distance error with respect to the true value of the parameter that the researcher is willing to accept.

There are no official statistics for cacao farmers. Therefore, to calculate the sample size, we use a population of 6000 cacao growers (Cacao Tumaco, nd), a variance of 1574.22 (Preciado *et al*., 2011), and a maximum error of five farmers. Parallel to this, we presented the project to the community councils with the participation of farmers and community leaders. The adjusted D&D (Raintree, 1987) and RIMISP (Escobar and Berdegué, 1990) methods allowed the characterization process. In the workshops, through brainstorming, farmers and technicians selected 18 qualitative (Table 1) and 20 quantitative variables (Table 2). These variables encompassed the semi-structured survey.

Table 1. Qualitative variables used in the characterization of the traditional cocoa production system in Tumaco, Nariño.

Code	Variable name	Modality	Label
V2	Farmer education	Primary	1
		Half	2
		Technical	3
		University	4
V7	Famer gender	Male	1
		Female	2
V8	Land tenure	Amediero	1
		Shared	2
		Own	3
V13	Main production system	Monoculture	1
		Forestry	2
		Agroforestry	3
		Agricultural	4
		Other	5

Continuation Table 1.

V14	Cacao companion species	Fruit and timber	1
		Banana	2
		Banana and fruit trees	3
		Miscellaneous	4
		Fruit trees	5
		Other	6
V19	Woody species usage	Timber	1
		Forage	2
		Shadow	3
		Does not have	4
		Does not know	5
V23	Type of domestic animals	Cattle and horses	1
		Poultry	2
		Rabbits and guinea pigs	3
		Does not have	4
		Miscellaneous	5
V25	Domestic animal facilities	Animal Husbandry	1
		Combination with trees	2
		In grasslands without trees	3
		Does not have	4
		Other	5
V26	Agricultural practices	Well managed (phytosanitary control, Fertilization, pruning, cleaning and irrigation)	1
		Moderately managed (absence of any management practice)	2
		Poorly managed (no fertilizer and absence of most agricultural practices)	3
V27	Costs per hectare	≤1000000	1
		> 1,000,000 to 4,000,000	2
		> 4,000,000 to 8,000,000	3
		> 8000000 to 11000000	4
		> 11000000	5
V30	Difficulties	Lack of agricultural technification	1
		Economic factors	2
		High temperatures	3
		External factors (pests)	4
V31	The income from the property is sufficient for the family sustenance	House and family expenses	1
		Production costs	2
		Both of the above	3
		A little	4
		No	5
V32	Loans	yes	1
		no	2

Continuation Table 1.

V34	Paid Loans	yes no It's paying No credits	1 2 3 4
V35	Technical assistance	Sporadically Weekly Every 15 days Monthly Never	1 2 3 4 5
V36	Transportation type	Horse Motorcycle Automobile Van Locally (in the village)	1 2 3 4 5
V37	Place of the farm's products	Locally (in the village) In the municpipality Outside the municipality	1 2 3
V38	Propositions for improving production systems	Improve Marketing (Pricing) Technification of crops Improvement of roads None	1 2 3 4

Table 2. Quantitative variables used in the characterization of the traditional cocoa production system in Tumaco, Nariño.

Go	Variable name	Unit
V1	Farmer age	Years
V3	Amount of Children	Unit
V4	Young people (15 - 30 years)	Unit
V5	Adults (31 to 50 years)	Unit
V6	Adults over 50 years	Unit
V9	Family wages	Wages
V10	Farm lots	Unit
V11	Total area of farm	Ha
V12	Cacao crop area	Ha
V15	Cacao density	Unit
V16	Banana density	Unit
V17	Fruit trees density	Unit
V18	Wood	Cubic meter
V20	Cacao yield/ha	kg
V21	Income for cacao	Pesos
V22	Income for agriculture	Pesos
V24	Income for Livestock	Pesos
V28	Family wages	Wages
V29	Hired wages	Wages
V33	Amount received in loans	Pesos

The sampling size was 218 cacao farmers randomly selected from the community councils of Rescate Las Varas, Alto Mira and Frontera, Bajo Mira and Frontera, and Rio Chagüi; they responded to the semi-structured survey. Then, for the validation process and gathering of biophysical information, in each community council, three farms with cacao were randomly selected. These farms comprehended the main spatial and temporal components and arrangements' distribution identified in the surveys and previous research.

Statistical analysis. The variables analyzed were those with coefficients of individual variation (CV) higher than the 30% threshold. Principal Component Analysis (PCA) and Multiple Correspondence Analysis (ACM) approach served to analyze the performance of qualitative and quantitative variables. The hierarchical classification, using Ward's distance method, allowed grouping the farms by their homogeneous and heterogeneous conditions. All the statistical processes used the SPAD software, version 5.6.

RESULTS AND DISCUSSION

Principal Component Analysis (PCA). Five components explained 50.86% of the total variability. The eigenvalues one and two explained the 27.75% of the contribution to the variation of this study.

The first component explains 14.54% of the variability (Table 3). The variables that contribute to this component are the labor force with a variable-factor correlation of 0.81 (V9:0.81), adults on the farm (V5:0.64), cacao yield (V20:0.57). In this group, these results suggest that the discrimination was a result of the presence of adult farmers who have low cacao yields.

The second component explains 13.21% of the total variability and is mainly made up of the income obtained by a producer, the producer's age (V1), the area of the cacao plantation (V12), the producer's school level (V2), and the whole area of the farm (V11) (Table, 3). These variables showed variable-factor correlations of the order of -0.57, -0.55, 0.55 and -0.48, respectively. Indicating that there is a directly proportional relationship between the low income of the producer and the variables mentioned above.

The third component explains 9.60% of the total variability made up of two variables: total area of the farm (V11) and the area of the cacao crop (V12), which presented in their order, a variable-factor correlation of 0.77 and 0.67, and they show that the largest area of the farm is dedicated to the cultivation of cacao.

The fourth component made a contribution to variability of 7.18%. It was mainly made up of the income variables of agricultural production other than cacao (V22) with a variable-factor correlation of 0.63 and the producer's age (V1) with a correlation of -0.45. The contribution of this variable is low and explains why cacao producers are vulnerable to factors that affect cacao productivity, having to resort to external sources to obtain sufficient income to be able to maintain their family nucleus.

Table 3. Variable-factor correlation of each of the variables on the first five components.

Variables			Variable-factor Correlation		
Id – Label	**1**	**2**	**3**	**4**	**5**
C2 -V1	0.02	-0.57	-0.42	-0.45	0.04
C3 -V3	0.46	0.55	0.33	0.02	0.11
C4 -V4	0.36	0.48	0.06	-0.04	-0.04
C5 -V5	0.64	0.42	0.12	0.02	-0.04
C6 -V6	0.52	-0.45	-0.24	-0.42	0.10
C7 -V9	0.81	0.24	0.07	-0.27	0.02
C8 -V10	0.02	-0.32	0.45	0.13	0.30
C9 -V11	0.07	-0.48	0.77	-0.05	-0.14
C10 -V12	0.11	-0.55	0.67	-0.03	-0.18
C11 -V15	0.38	0.02	-0.05	-0.05	-0.04
C12 -V16	0.49	-0.41	-0.07	0.24	-0.01
C13 -V17	0.26	0.00	0.09	-0.25	-0.28
C14 -V18	0.07	-0.27	-0.12	0.15	0.27
C15 -V20	0.57	-0.39	-0.24	0.25	0.05
C16 -V21	0.26	-0.40	-0.21	0.16	0.02
C17 -V22	0,41	-0.03	-0.15	0.63	-0.01
C18 -V24	0.00	0.01	0.07	0.18	0.71
C19 -V28	0.08	-0.07	-0.23	0.29	-0.58
C20 -V29	-0.17	-0.11	0.05	0.38	-0.18

Finally, the variables that contributed the most to the formation of the fifth component were income from livestock production (V24) and family labor (V28), which showed variable factor correlations of 0.71 and -0.58, respectively; this factor explained 6.33% of the total variability (Table 3). Livestock activity contributes little or nothing to the activities of producers, which allows us to infer that the diet of these producers comes mainly from wild animals or fish. They should establish programs to promote these species, especially minor species as a source of protein in the diet of producers and generation of income in the short and medium-term.

When analyzing the five factors, the most relevant variables for this study are the producer's age and education. In this area, it is striking that adults are responsible for maintaining the family nucleus with resources from some productive units, which have low yields. This explains to a large extent, the marginality of cacao producers and the limited capacity to project their farms and their families in search of a better future.

The variable that discriminated the Tumaco farmers was the low level of schooling; similar results reported by Pabón *et al*. (2016), when they carried out the socio-economic and productive characterization of cacao cultivation in the department of Santander, Colombia, finding a basic level of education for the surveyed farmers. This is a condition that does not show great variation over time since research carried out by Espinal *et al*. (2005) report the same characteristic. These painful statistics also agree with those presented in the diagnosis on the education of the Territorial

Ordering Plan of the Municipality of Tumaco (2008), where 40% of adults are illiterate. This is a recurring characteristic over time, indicating that literacy programs have not been effective.
In Colombia, cacao growers have low levels of education since there is a degree of illiteracy of 16%, 64% elementary, and only 9.4% secondary education (Oliveros and Pérez, 2013). With regard to higher education, only 0.8% of them have completed technical or university studies (Vásquez-Barajas *et al*., 2018). These statistics exceed the national average of 12.6% (DANE, 2016) and alert the government and especially those responsible for education and agricultural extension services to generate appropriate public policies to improve the education system. The age of the producer is a determining aspect for the future of cacao farming since, in this study, the owners of the farms are older than 50 years old. This makes the transfer of technology and the improvement projects of the productive units not easily adoptable and transmittable to the new generations, putting great uncertainty in the future of cacao farming in the region. For instance, in Tumaco, 60% of the cacao producers are between 40 and 65 years old (Preciado *et al*., 2011); 45 and 54 years in Santander, Colombia (Mata *et al.,* 2018), and over 50 years in Veracruz, Mexico (De la Cruz-Landero *et al.,* 2015).

The variables mentioned above are related to the farmer's age, labor force, family labor, and low income. Another variable that draws attention is the productivity of cacao, which in all the aforementioned studies, including this one, is very low and is ratified by Agronet (2018) of 200kg ha^{-1}. This low yield is worrisome, and it is the result ageing and low-yielding cacao trees, scarce technification, low generational change, and limiting cacao diseases such as *Moniliophthora roreri* HC Evans *et al*. (1978) and *Moniliophthora perniciosa* (Stahel)Aime) (Afoakwa, 2016). Under these conditions, cacao producers are clearly marginalized and forced to compensate their low income with other activities (Espinosa-Alzate and Rios-Osorio, 2016) such as illicit use crops (UNODC and Acción Social, 2008).

According to the aforementioned facts, traditional agroforestry faces many worrisome troubles that complicate its success, especially technology transfers. Despite this, the government and institutions such as Agrosavia and Fedecacao, the private sector, and some NGOs offer cacao technological technification programs that include technical assistance, advice, supply of seed and vegetative material, cloning, rehabilitation, and renewal of old crops among others (Oliveros and Pérez, 2013), but with low effect on cacao growers' welfare. A better understanding of the socioeconomic reality of the cacao farms and the wellbeing they provide can facilitate the adoption of efficient policies and measures to enhance their regional effect (Hall *et al*., 2010).

Classification analysis. The classificatory analysis grouped the farmers into four large clusters. These allowed us to generate the typologies of a set of categories or types through a set of similar characteristics for a specific group of farmers (Figure 1).

Group 1 represented 25.86% of the total farms surveyed. This group displays a higher average of cacao productivity (560.30kg $year^{-1}$) compared to the general average of 244.83kg $year^{-1}$. In addition, these farmers showed outstanding values in the age of the farmer (V1), adults over 50 years old (V6), and the largest amount of timber on the farm (V18). Despite having a marginal condition, this group is the one with the highest income (Table 4).

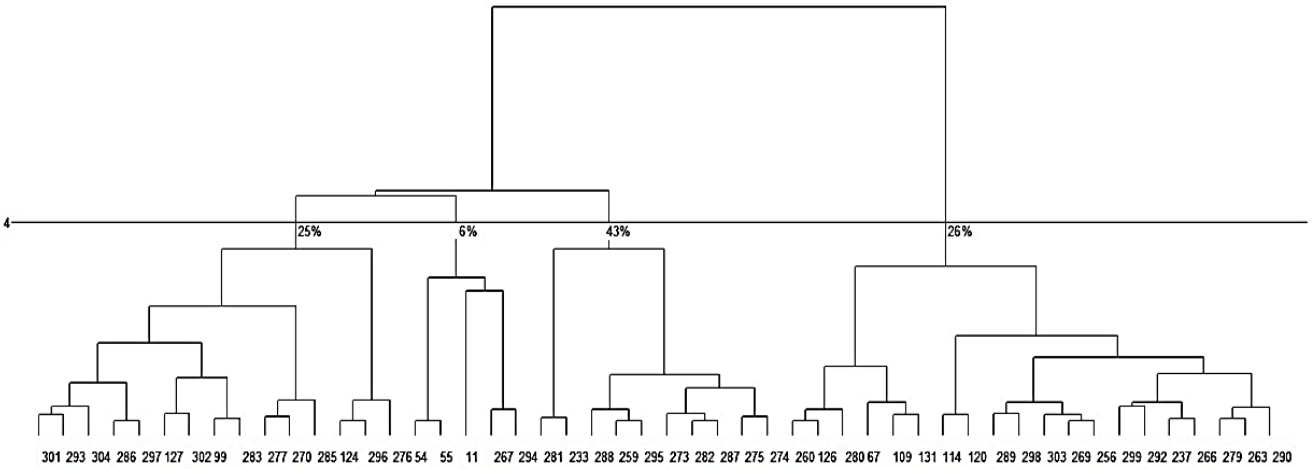

Figure 1. Group formation based on a hierarchical analysis of quantitative variables.

Table 4. The number of farms that make up each of the four groups, and the weight of the variables in each group.

No.	Farmers	Variables and weight
1	44	V21 (70%); V18 (10%) , V20 (10%); V1 (8%) y V4 (2%) V3 (2%)
2	11	V16 (92%); V29 (4%); V11(3%), V12 (3%), V10 (1%)
3	76	V21 (50%); V22 (40%), V15 (9%), V5-V6-V9-V13-V1 (1%)
4	46	V22 (96%); V1 (2%); V11 (1%), V9-V5-V12-V4 (1%)

Group 2 represents 6.21% (Table 2). This group shows values higher than the general average in the variables: The farm area (V11), with 17.82 ha compared to the average (5.22 ha), dedicated to the traditional production of cacao (V12). They also have a large amount of plantain (V16), an important component in the cacao plantations of the Pacific coast of Nariño, which is used to a great extent for sale and self-consumption.

The extension of these farms forces the owner to acquire hired labor since family labor is not enough to supply the labor force. When the income does not allow the producer to hire external labor, he is forced to abandon some lots on the farm. Most of the farms are in Community Councils such as Alto Mira and Bajo Mira, where agriculture without modernization predominates.

Group 3, encompasses 42.94% of the farmers (Table 4). This group has lower values than the general average in some variables such as the income from different agricultural activities (V22), and the number of plantains on these farms. In this group, marginality is more accentuated due to the low productivity of the farms, which forces farmers to look for external jobs.

Finally, the fourth group encompasses 25.99% of the surveyed population. The farms belonging to this group have values much higher than the overall average in variables such as a labor force (V9), with an average of 4.13, compared to 2.02 for the general average.

The results of the groups' classification inferred that there are marked differences in the

traditional production systems that go from extensive farms to small profitable units, which must be intervened differentially. In the same way, there is no enough labor force to hire.

Evidently, the families of cacao growers have a nucleus made up of infants, youths and adults, being the last ones who always generate incomes for the family from different agricultural activities. However, the labor force from youth and adults mainly goes to cacao-related activities. On the other hand, the farmers of the last group, despite being younger, call the attention due to their low performance in most of the cacao yield-related variables; therefore, their income comes from sources other than cacao. This group is the risky one because they are not relieving adult cacao growers, but working on illicit use crops.

The low participation of young people in cacao activities is transversal to all typologies and has great specific weight in the fate of cacao systems, taking into account its differentiation in international markets as cacao with superior organoleptic characteristics (FEDECACAO, 2019), which makes it attractive for the chocolate industries. However, there are not promising strategies to increase the local yield. This activity could result in a pole of development for traditional cacao farming if it is linked to the youth and children population.

To sum up, the four groups show outstanding characteristics such as producer income, cacao production area, diversity of crops, and family nucleus size. Sánchez and Suarez (2014), differ by having a single variable marking the differences of the three groups, which is the size of the farm (large, medium, and small); this variation may be owing to the surveys carried out for each case have unlike variables, or that each researcher gave them a distinctive importance. In the case of farm productivity, it can be inferred that their diversity is a preponderant factor for their persistence, in addition to cacao crops. This is confirmed by Espinosa-Álzate and Rios-Osorio (2016) who indicate that the diversity of activities such as fishing, agriculture of various types, harvesting of wood and wild products, hunting, and mining, which are practiced daily by river dwellers, make it possible to cacao growers thrive in this region.

Multiple Correspondence analyses (MCA). The descriptive analysis of nominal categorical data evaluated from the surveyed farmers shows 15 variables explaining 65% of the variability, a typical value for qualitative variables. Underlying structures were detected and represented in a set of data, which in the first five factors together explain 29.82% of the total variability. The initial factor explains 8.62% of the variability; the second, third, fourth, and fifth factors explain 6, 5.50, 5.15% and 4.55%, respectively.

From the analysis of the contributions of the variables to the conformation of the axes, the variables that most contribute to the conformation of factor one are the producer's education level (V2 = 14.7), type transport (V38 = 13.8), animal facilities (V25 = 13.1), animal species (V23 = 8.6), farm loans (V32 = 8.6), loans paid (V34 = 8.6), use of timber species (V19 = 7.7), commercialization of products (V37 = 5.0), technical assistance (V35 = 4.8), and enough income to satisfy basic needs of the family (V31 = 4.3) (Table 5).

Table 5. Contribution of the qualitative variables evaluated in the cacao farms.

Variables	Higher weight categories	Weight contribution by a factor				
2	1	0.69	0.25	0.18	-0.10	-0.07
	2	-0.67	-0.23	-0.13	-0.88	0.50
7	1	0.09	-0.16	0.04	0.34	-0.04
	2	-0.08	0.14	-0.04	-0.30	0.04
14	1	0.07	0.22	-0.42	-0.21	-0.45
	3	-0.53	-0.05	-.01	-0.39	1.07
	4	0.52	1.06	0.00	0.33	0.84
25	1	-1.09	-0.31	-0.34	0.72	0.20
	4	0.64	0.65	-0.37	-0.16	-0.16
	5	0.64	0.35	-0.19	0.12	0.08
30	1	-0.07	-0.01	0.25	-0.36	-0.09
	2	-0.29	-0.19	-0.48	0.19	0.14
	3	0.22	0.00	0.05	0.27	0.05
37	1	0.23	-0.18	0.06	0.08	0.11
	2	-0.74	0.57	-0.18	-0.24	-0.36

As shown in Table 5, the discriminant variables linked to the cacao agroforestry systems refer to livestock species, the difficulty for commercialization, lack of technical assistance, and timber species. The analysis yielded socioeconomic information about the relationship between the places of commercialization of products and the means of transport, which are very precarious or non-exist.

Incomplete primary was the predominant level of education of the farmers (V2:C1) (Read variable 2 and category or modality 1). Regarding the gender variable, the property owners are male; wives manage the home and take care of children.

Timber is the main companion component in the cacao system, along with some fruit trees and bananas (V14:C1). Most of the timber is for sale, a very particular condition on the Pacific coast of Nariño while fruits and bananas are for self-consumption. The multiple correspondence analysis also indicates low presence of domestic animal species (V25:C4), without facilities nor technification.

Regarding the costs for the production of cacao per hectare, the majority of respondents show a value less than or equal to one million pesos ($ 1,000,000) (V27:C1) per annum; costs that are insufficient for the management of the farms, and that are assumed by the producer through his labor force. In the same way, the productive systems satisfy the needs and expenses of the household and farm (V31:C3). An aspect that draws attention and demonstrates the little business knowledge of the producers who indicate that, despite these low yields and the large production units, they have not resorted to requests for agricultural loans for investment. In the same way, the qualitative analysis indicates that the respondents have low technical assistance, finding that only a paltry percentage receives visits every 15 days. Besides, their main transport way is the river, and the marketing has strong intermediation, which according to

variable 37, is carried out between different villages or in the urban area of the municipality of Tumaco; a place that does not offer fair prices, nor does it has the infrastructure to absorb the diversity of products obtained in the farms.

Finally, the analysis indicates that the greatest difficulties that farmers face come from the low technification of cacao crops, infrastructure, industrialization, and commercialization of agricultural products. The low competitiveness of the cacao-agroforest farms related above is similar to the one by De la Cruz-Landero *et al.* (2015), and Pabón *et al*. (2016) which show the same socioeconomic limitations. On the other hand, Mata *et al*. (2018) give greater relevance to the variable type of agroforestry system that the farmer has with respect to the cultivation of cacao, but they coincide with the age of the producer and amount of the family labor force.

Criollo *et al*. (2016) point out that the most relevant variables are altitude, type of fertilizer used in planting, cultivation with fruit trees, management of fruit trees, renovation, area of cultivation, number of wages used in the production process, knowledge of good agricultural practices, and farm production, which differs from the results of this case study.

Classification analysis. The classification analysis based on the qualitative characteristics for the surveyed farms in the municipality of Tumaco allowed the formation of five groups (Figure 2).

The first group, made up of 31 farmers, represents 17.51% of the surveys carried out (Table 6). This group has very close values to the general average, indicating that 86% of them have not paid loans (V32:C1 and V34:C1). They also market their products locally; an activity that brings them low income, which does not allow them to save money.

Table 6. Description of the groups or classes formed in the MCA of the surveys carried out in the cacao farms of the municipality of Tumaco.

Group	No. Cacao growers	Variables by group
1	31	32 , 34 , 2, 37 y 25
2	13	14 y 13
3	29	19 , 25, 35 , 36 y 31
4	47	2 , 34, 32 , 37 y 25
5	57	25 , 23, 19 y 34

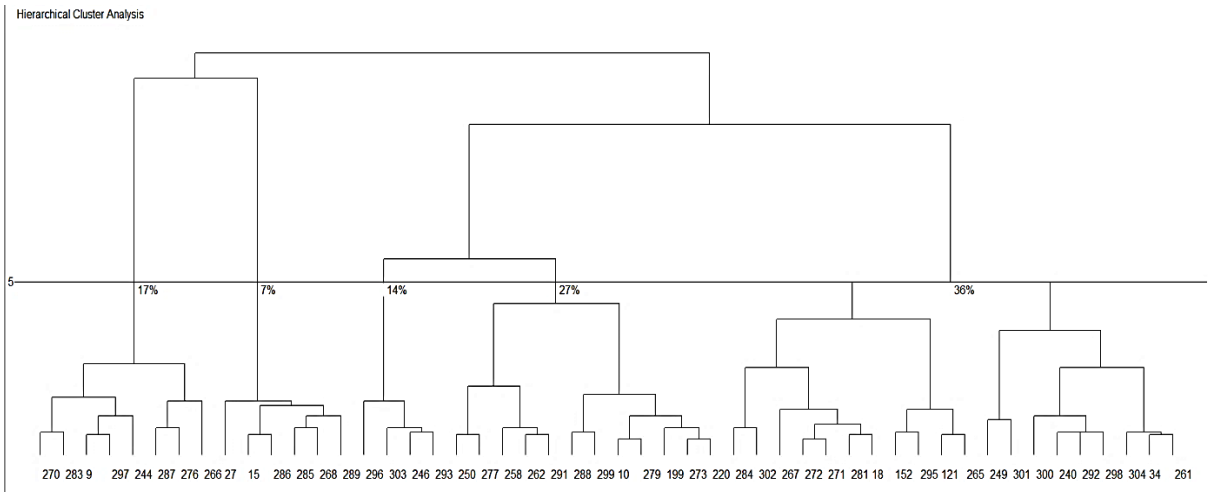

Figure 2. Conformation of groups according to the qualitative characteristics evaluated in the surveys carried out in the cacao farms of the municipality of Tumaco.

The second group represents 7.34% of the total population; 100% of them have elevated diversity of companion species, identifying as "others" the most common companion species category; this is reflected in the high rate of diversity found in the cacao plantations of the Pacific Nariño. Regarding all the farms that make up group 2, they state that they have a non-technical "agricultural" production system in which the cultivation of cacao prevails against companion species.

Group 3 comprehends 16.38% of the total number of respondents; 43.75% of them demand support to improve marketing (V38:C1) through standardization of prices for cacao and other products; in the same way, farmers of these group use horses as a transport mean (V37:C1), keeping them in the house or in the farm (V25:C5). These animals allow them to transport the inputs farm´s products. This group also receives regular technical assistance every 15 days.

Group 4 represents 26.55% of the total number of people surveyed. This group has high contributions in the variables V2 C1 and V37 C2, indicating that 45% of them have primary education and carry out the commercialization of products in Tumaco. They have access to technical assistance (V35:C3). Likewise, variable 32:C1 shows that farmers have obtained loans to improve their cacao production system.

This group has optimal conditions for marketing cacao locally, with a high frequency of technical assistance visits and capital derived from loans, which according to the results in variable 34, only 28% have been paid.

Finally, 32.2% of the total respondents encompass group five, which 95% of them has their own farms (V8:C3), they have not loans, use terrestrial transportation for their products (V36 C4) and use diverse tree species as a companion of the cacao crop (V14:C6).

In this analysis, the groups are discriminated by the variables mentioned above with the appearance of small subgroups. Regarding significant variables for this study, we can highlight the low loan access by farmers to invest in their crops, which is relevant and similar in terms of what is established by De la Cruz-Landero *et al*. (2015). Colombian government have increased loans budged; however, the number of the loan requests has not increased (Finagro, 2018), since the requirements for accessing a loan are very expensive and not profitable for cacao smallholders.

In another subgroup, the companion species also stand out; they are very diverse going from fruit to timber trees, agreeing with the studies by Preciado *et al*. (2011), Pabón *et al*. (2016) and Mata *et al*. (2018). They point out that, despite the positive effect of diversity (Hooper *et al*., 2005), the lack of technical assistance, always triggers low income. This inhibits the adoption of more advanced farming practices, including the use of pesticides and fertilizers (Hainmueller *et al*., 2011).

Criollo *et al*. (2016) in their study of the productive systems in Nariño, formed four groups defined by the association of fruit trees, technological assistance, crop renewal, and type of production system. For the technical assistance variable, it is compatible with this study, but with the difference that in their study, UMATA office offers it, while in Tumaco most of the agricultural extension is occasionally carried out by NGOs programs.

There are other significant variables highlighted by many authors which are not relevant for this

study like genre of the producer, marital status, land tenure, age of plantation (De la Cruz-Landero *et al*. 2015), average cacao production, presence of plagues and diseases (Pabón *et al*. 2016), average income, agroforestry arrangements per producer, land tenure, income per family (Mata *et al*. 2018), and possession of the land. For this study, the characteristics that discriminated against the populations were the age of the producer, cacao yields, lack of generational change, aging farms, product diversity, and low access to loans.

Traditional cacao farms, due to their great diversity of timber and non-timber components as well as the diversity of cacao ecotypes adapted to local conditions (Widyasary and Susandarini, 2020), result in a source of genetic and biological information useful to develop breeding programs for pest and disease resistance and yields, which is very important to increase farms' productivity.

The cacao production system in Tumaco turned out to be complex with multiple components interacting with each other and deliberately modified by the producers, receiving the influence of external factors that were complementary for its functioning as a family productive activity. One aspect that draws the attention is the low competitiveness of this system; an aspect resolve in order to make cacao farming attractive to young people and take advantage of their quality and proximity to the port. Otherwise, the socio-economic problems of this region will continue.

Additionally, cacao in Colombia would be a post-conflict crop and replacement for the illicit ones. To promote this crop in the post-conflict zones and in the displaced population, entrepreneurship can be used as a competitiveness mechanism (Pitre-Redondo *et al*., 2017). Through the creation of farmers' organizations, the displaced population has the possibility of obtaining economic independence with the necessary tools and constant training to consolidate their business ideas in a stable and competitive way (Garrido-Hurtado and Valderrama-Cardona, 2016).

CONCLUSIONS

The socio-economic analysis of the traditional agroforestry cacao system (*Theobroma cacao* L.) indicates that farmers evidence many troubles to reach the cacao equilibrium threshold. The discriminant variables were yield, farmer age, cacao crop age, technology, pests and diseases and loan access.

The traditional cacao agroforestry system is not an attractive activity for young people or investors given its marginality and low economic projection. Government strategies should be established to recover them. In addition to providing sustenance, they must generate income that allows cacao smallholders to improve their farms while making some savings.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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