Model to Estimate Determinants of an Area Harvested in Cocoa Production Systems

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Abstract **–The stakeholders of the cocoa sector should be introduced with determinants that influence an area of cocoa harvest. Objective of the study is to identify the determinants of a harvested area in small cocoa production units in Huila. A correlational method, cross section, and quantitative approach was used with data from the last National agricultural census. Results of the study revealed that major area does not use credit, advice and irrigation increase the area while the organic fertilization is positive. Those displaced by violence have less harvest area and the primary and secondary sectors are positively associated with an increase in area. It can be concluded that the determinants of harvested area identified in this study exhibit a low management behavior in the agronomic practices of cocoa producers that limit the expansion of the harvested area in Huila. This aspect affects the medium and long-term economic sustainability of this agricultural activity. Therefore, continuous training and education of the producers are essential in order to improve this problematic situation.**

Keywords **– Cocoa, determinants, harvested area, sustainability, cultural practices.**

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1. Introduction

Cocoa production in the department of Huila, Colombia, plays an important role in the socioeconomic environment of the region.

According to data from the National Federation of Cocoa Growers (Fedecacao). About 3,500 families are dedicated to harvesting approximately 7,000 hectares, which generated a production of 4,197 tons of dry cocoa beans in 2020, representing 6.6% of national production [1]. However, the smallholding model with low productivity and profitability prevails in the region, where most producers define themselves as farmers [2].

The climate in the Huila region is characterized by rainfall that varies between 668 and 1500 mm per year, with dry periods in the months of January, February and July, August and September, high monthly solar radiation (1498.2 micromole m2/s m) and solar brightness (6 hours of sun/day). Due to these climatic conditions, the adaptation of agroforestry systems is required for its cultivation, as pointed out by Ordonez et al [3]. In this sense, the cultivation of cocoa under shade is widely recommended to face climate change and reduce deforestation [4]. In addition, the UN and the OECD identify cocoa as an environmentally friendly crop [5].

Understory configuration necessitates the use of pruning to balance production risks in a changing environment [6]. Likewise, the choice of shade is a decision variable that provides economic, environmental and sociocultural benefits [7]. Cocoa develops very well in production systems under shade, either through conventional or organic agriculture [8].

The cocoa produced in Huila has an excellent quality, although the quantity offered can be increased. Currently, it is negotiated in a market that promotes the commercialization of grain as a basic product, centralized from the years 1925 in New York and 1928 in London, which have become benchmarks for setting world prices [9].

According to the International Cocoa Organization [10], worldwide, approximately five million metric tons of dry grains are offered per year, of which 75% comes from West Africa. However, the cocoa produced in Colombia, and particularly in Huila, has great potential to position itself in the international market as a premium and high-quality product.

To achieve this, it is necessary to improve the productivity and profitability of small producers through the implementation of innovative technologies, the strengthening of producer organizations and the promotion of sustainable agriculture. In addition, joint work is required between governments, companies and international organizations to encourage investment in the cocoa value chain and support the development of new markets and products derived from cocoa. A challenging future is foreseen for the economic sustainability of cocoa, given the increase in demand and because it depends directly on the expansion of harvested land and on the fact that new harvestable land is not exhausted [11]. In Colombia, enhancing social cohesion among cocoa producers helps minimize the risks of violence, illicit crops, and inefficiency [12], [13].

In this sense, the objective of the research is to identify the factors that determine the harvested area of the cocoa crop in Huila, which may be useful for future research on the economic sustainability of cocoa and for the implementation of expansion programs, such as the one carried out in the state of Para in Brazil [14].

2. Materials and Methodology

This study focused on the cocoa system in the Huila region, using a quantitative methodology with secondary data and computer tools (Stata version 13). For this, a variety of databases were used, such as the National Agricultural Survey, the Comprehensive Care and Reparation Unit for Victims, and the Municipal Economic Importance Index, to build models that allow the evaluation of decision-making processes in the sustainable management of the cocoa harvested area.

Multivariate techniques that combine computer mathematics with social, economic and agricultural sciences were used to identify variables and indicators that determine the sustainability and growth of the cocoa harvested area. Complying with agronomic rules by producers is not enough to guarantee the expansion of the harvested area without an environment that offers an appropriate environmental and safety offer for the development of this economic activity.

Therefore, a robust prediction on the harvested area of cocoa requires a social and solidarity economy approach, using methods of econometrics and social engineering, with deductive reasoning.

The ultimate goal is to achieve sustainable management of the cocoa system in Huila, taking into account not only agronomic aspects, but economic and social aspects, too [15], [16].

To carry out this study, a multiple linear regression model was developed with cross-sectional data. The proposed model has a dependent variable y (harvested area) and a group of independent explanatory variables x. To find the parameters, the model is estimated by means of the Ordinary Least Squares (OLS) method. The multiple regression model can be written as follows:

$$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + u_n \quad n = 1,2,3,\dots,N \qquad (1)$$

where the intercept or constant of the model is called β_0. The parameter β_1 as well as the others, measures the change obtained in respect to x_1, maintaining the other factors in their mean. The term u_n is the so-called error, which contains the multiple random effect variables and allows verification through the probability criteria that the p-value of the partial regression coefficients is different from 0 [17].

To analyze in what proportion each variable explains the variability of the variable of interest, which is the harvested area, three models are developed. The first model includes variables related to the regional GDP of the primary, secondary and tertiary sectors, and the violence index. The second model adds to the previous model, variables typical of the cocoa production system such as credit, advice, irrigation system, organic fertilization, and no fertilization. The third model includes the variables of the number of displaced people and the number of permanent people in the cocoa activity (See Table 1). For each case, 6,675 observations were processed, which correspond to the same number of productive units.

The variables discussed and mentioned above come from the ENA 2020 database and the Unit for Comprehensive Care and Reparation for Victims, following the methodology proposed by [18], as presented in Table 1.

Table 1. Variables used in the estimation of the Model

Dependent	**Description**	**Source of Information**
Ln Harvested Hectares	Number of hectares harvested in natural logarithm.	ENA
Independents	**Description**	**Source of information**
Ln Primary GNP Sector	Municipal Value Added of the primary sector in natural logarithm.	DANE
Ln Secondary GNP Sector	Municipal Value Added of the secondary sector in natural logarithm.	
Ln Tertiary GNP Sector	Municipal Value Added of the tertiary sector in natural logarithm.	
Violence index	Built from the methodology of Quintero, Lahuerta, & Moreno (2008) and following the work of Martinez & Zuleta (2019).	Unit for Comprehensive Care and Reparation for Victims.
Credit	Binary: Takes the value of (1) if you requested any credit for the development of agricultural activity	ENA
Counsel	Binary: Takes the value of (1) if they received technical assistance or counsel.	
Without irrigation	Binary: Takes the value of (1) if there is no irrigation for the crop.	
Organic fertilizer and does not fertilize	Binary: Takes the value of (1) if organic fertilizer was used in the crop.	
Displaced	Binary: Takes value of (1) if head of the household is displaced.	
Does not fertilize	Binary: Takes the value of 1 if it does not fertilize the crop.	
Number of permanent individuals	Number of people permanently in agricultural activity.	

Source: our own

Once the variables to explain the proposed problem have been defined, the variance factor (VIF) is calculated to identify multicollinearity issues, resulting in an average of 15.33, where the variables Ln Secondary GNP Sector and Ln Tertiary GNP Sector had a *VIF* of 85.34 and 69.90 respectively, which gives sufficient evidence to remove them from the model.

The stepwise method for the selection of the *stepwise* variables was used with reversed selection criteria, to eliminate the terms with a $p \geq 0.2$ for each estimation, but all were greater, that is to say that no variables were omitted, but after running the models without multicollinearity issues and with the variable selection criterion, it is evident that the variables organic fertilizer, does not fertilize, and displaced are marginally and statistically significant in the model, therefore they are not taken into account in the estimate.

In addition, the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity is performed, with a value of Prob > chi2 = 0.0000, indicating that the null hypothesis of constant variance in each estimation is rejected. To correct the problem, run the models with robust standard errors, as suggested.

Lastly, the F statistic is calculated to test the null hypothesis that the value of R is equal to zero. The results of the statistic, according to its statistical significance, do not indicate that there is a linear and significant relationship between the explained variable and the explanatory variables.

3. Results and Discussion

The interest in knowing how the cocoa system operates to achieve goals in harvested areas and economic sustainability, allowed us to trace the sources of data accessible on the web, from state institutions, on harvested areas, cultural practices, territorial GDP, displacement and carry out a correlation analysis between variables, results that are presented below. The GDP of the Department of Huila for the year 2014 was approximately 12.7 trillion pesos, represented by 27.9% by the activities of the primary sector, 19% by the secondary sector and 53.1% by the tertiary sector.

The activities of the primary sector, the regional GDP in monetary terms, reached the figure of $3.54 trillion. For this year, according to statistics from the Departmental Secretariat of Agriculture and Mining, the production of dry cocoa beans was 3,301.6 tons, with an average price of $5,029,000, which meant in monetary terms $16.603 trillion, 0.47%. of total regional GDP.

In this context, the results of the estimation of model 1 suggest that a 1% increase in the primary sector increases the cocoa harvested area in the Huila department by 0.11% (See Table 2).

In model 2, by including other variables, the positive relationship persists and the harvested area increases until reaching 0.151% (See Table 2). Including all the variables in model 3, the increase in the harvest area is 0.158%.

Despite the fact that the secondary sector contributed $2.4 trillion to the regional GDP in 2014 in monetary terms, this variable was not enough to explain the variations of the dependent variable. On the other hand, it is estimated that the production of the tertiary sector reached 6.7 trillion pesos during the same year. However, the municipalities of Elías, Altamira and Nataga only represented 0.92% of the sector's GDP, while Garzón, Pitalito, and Neiva contributed 61.75% similar to what was observed in the secondary sector. Despite this evidence, the tertiary sector variable was not included in the model and its impact was not taken into account.

The economic variable analyzed in the first model explain 2.78% of the variations in the harvested area, but by including the violence index, this explanation increases to 4.09%. This variable is included in the model in order to determine the relationship that violence has with the area harvested by municipality, which turns out to be positive for the correlation with the area harvested for the three estimates made.

By including new variables in model 2, the explanation of the variations of the variable of interest increases by 3.41%.

Table 2. Results of the model of determinants of the cocoa harvested area in the Department of Huila – ENA 2014

	(1)	(2)	(3)
Ln_PIB_1	0.1129**	0.1501***	0.1587***
	(7.39)	(9.30)	(9.68)
Def violence index	0.2180***	0.2515***	0.2642***
	(11.36)	(12.52)	(12.94)
Credit		-0.1443***	-0.1468***
		(-4.61)	(-4.62)
Counsel		0.1037***	0.1242***
		(4.13)	(4.86)
Irrigation		-0.1839***	-0.1835***
		(-7.11)	(-6.97)
No fertilizer		0.3769***	0.3747***
		(14.83)	(14.48)
People permanently in cocoa activity			0.0048***
			(5.62)
cons	-0.9862***	-1.404***	-1.522***
	(-15.86)	(-20.46)	(-21.78)
R2	0.0409	0.075	0.0834
F-test	154.988	120.536	111.703
Prob > F	0.000	0.000	0.000
Observations	9.675	9.675	9.675

t statistics in parentheses
$* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

The results of the estimations under the regression model show the preponderance of small producers in crops with an average harvested area of 1.01 hectares per productive unit. Regarding the credit request variable, the harvested area is 0.95 hectares, while the harvested area of those who did not request credit is 1.02 hectares. Those who requested credits for agricultural activity, have less harvested area compared to those who did not request it, as indicated in the results of model 3, contrary to what was theoretically expected, in the sense that producers use credits to improve the productive system, which would result in the maintenance and expansion of the harvested area. The productive units related to the credit application obtain 17.7% less harvested area compared to those who did not request any type of credit for agricultural activity.

In relation to the technical assistance variable, 47.96% of the cocoa producers received some type of technical assistance or counsel to have better results in the production of the crop. Those who received counsel had an average harvested area of 1.02 hectares, while the average for those who did not receive advice was 0.99, without much difference. However, for the general model, those who had counsel managed to have 33.8% more harvested area compared to those who did not have any type of assistance or counsel.

For the irrigation variable, it is evident that the use of some type of water irrigation for the cocoa crop helps to have better results in the harvested area. Those who had irrigation, on average, had a harvested area of 1,067 hectares, that is, 0.189 hectares more than the areas where some type of irrigation was not used. The results indicate that there is 18% more harvested area when there is some type of irrigation in the crop.

By including the variable of does not fertilize, referring to the non-use of some type of fertilizer for the development of the crop, the results show that those who do not use fertilizers have 37% more harvested area. It is taken into account that 36.67% did not fertilize the crop and that only the harvested area is being used as an explained variable. However, when estimating a new model determining the yield of cocoa in tons per hectare, the relationship is positive, that is to say that those who use fertilizers have a slightly higher yield per hectare compared to those who do not use it, but it turns out not to be statistically significant for the explanation of the model.

The number of permanent individuals in the activity is positively related with the increase in the harvested area an individual that is permanently added to the cocoa cultivation activities, increases the harvested area by 0.48%.

It is inferred, therefore, that maintaining and expanding the harvested area of cocoa does not occur in a vacuum, it is a system that is part of an ecosystem, in which humans, plants, soil, animals, and the environment interact [19].

4. Conclusion

This study explored the determinants of the area harvested in cocoa farms in the Huila region in 2014. The results were based on the combination of productive, economic and social information, obtained from the National Agricultural Survey (ENA) for that year.

Important variables were identified, such as credit applications and the non-use of irrigation in the crop, which influenced the decrease in the harvested area. On the other hand, it was observed that having advice or technical assistance and increasing the number of permanent people in the agricultural activity helped to increase the harvested area.

It is important to point out that a non-significant relationship was observed between the use of organic fertilizers and yield or harvested area, which was counterproductive with theory and practice. It is necessary to deepen future research to understand the alternatives that explain why those who do not use fertilizers obtain a higher harvested area compared to those who use some type of fertilizer.

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