Model for Managing Economic Sustainability in Small-Scale Cacao Producers

Alberto Ducuara Manrique [1], Nicolás Arturo Nuñez Gomez,[1]
Alfonso Manrique Medina [1]

[1]*Universidad Surcolombiana. Neiva, Colombia*

***Abstract* - In Huila, Colombia, small cacao producers (Theobroma cacao L) carry out their productive activities using traditional agroforestry practices, within an economic environment of globalization and free market. However, despite having a centuries-old cacao culture, cacao production systems show evidence of not being economically sustainable and may lose their function in the long term. The purpose of this article is to present the research findings to formulate a methodological model that ensures economic sustainability for cacao production systems, conducted at the Universidad Surcolombiana. The proposed new methodological model is based on calculating eleven indicators of financial sustainability for the cacao system, covering production, management, and marketing approaches and their subsequent synthesis into five indices, using techniques for standardization, weighting, and aggregation of indicators. The empirical results obtained through surveys of 228 cacao producers and 13 experts served as the basis for deriving economic sustainability indices, which reveal the heterogeneity in the management of cacao production systems and classify them into five groups.**

It is concluded that 6.58% of the plantations have very low sustainability, 22.81% have low sustainability, 47.37% are moderately sustainable, 21.93% have high sustainability, and 1.32% have very high sustainability. It also identifies an opportunity to increase the productivity of the cacao system in Huila by 60%.

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Corresponding author: Alberto Ducuara Manrique,
Universidad Surcolombiana. Neiva, Colombia
Email: alduma@usco.edu.co

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1. Introduction

Cacao (Theobroma cacao L.) is a perennial crop that produces raw material for the culinary industry, due to its positive impact on human health, including antioxidant and anti-inflammatory effects. The industry has been able to effectively capitalize on these healthy attributes of cacao beans, marketing a wide variety of brands and presentations that highlight the nutritional virtues [1].

According to data from the National Federation of Cacao Farmers (Fedecacao), in Huila, 4,197 metric tons of dry cacao beans were marketed in 2020 [2]. Eighty-five percent of this production is attributed to small farmers [3] who, on average, harvest 1.1 hectares, demonstrating productivity levels of about 0.5 metric tons per hectare. Most plantations implement traditional agronomic practices, carried out by the farmer's family nucleus [4]. Like other countries in the Americas, production is primarily focused on varieties known as fine and aroma cacao, which is generally marketed under the category of ordinary cacao [5].

Small cacao producers face a significant challenge due to their limited bargaining power against a global oligopsony, which collectively holds between 60% and 80% of the volume traded on the New York and London [6] exchanges. Locally, demand is mainly concentrated in the Compañía Nacional del Chocolates Casa Luker, mediated by small intermediaries located in the producing territories.

To address the research, different authors were considered, such as [7], who provides a theoretical framework for economic sustainability, supported by conceptual models at the organizational level with various levels of management hierarchy. Previous works to measure sustainability with indicators include the "Indicator-Based Sustainability Assessment Framework" (IBSAF), created to address various dimensions and levels of agricultural sustainability in small farming units [8], [9].

Furthermore, in [10], sustainability was studied using a set of economic and social sustainability indicators and Sustainability Indexes (SI), among types of shaded National Cacao and the CCN-51 variety, in the province of El Oro, Ecuador. Another reference research approach is the modeling of the cacao production chain in Colombia, under the general theory of dynamic systems, to address the behavior of sustainability based on international market cacao prices [11,12].

Previous works such as the Farm Household Model (FHM) developed by [13] in Africa are included in the theoretical framework, which were used to assess the socioeconomic sustainability of cacao plantations in Ghana, incorporating the concept of shadow prices in the consumption of producing families' households.

Other modeling approaches can be found such as the "Stochastic Compound Error Frontier" meta-production technique proposed by [14] to evaluate productivity in cacao agriculture in Cameroon, Ghana, Nigeria, and Ivory Coast. This approach considers the random setbacks beyond the control of farmers, such as weather conditions, lack of incentives, imperfect competition, and poor management, studied holistically, seeking to find solutions to the problem of low yields.

In Oyo State, Nigeria, the relationship between factors in Cacao Development Units (CDU) such as age, skills of the producers, economic benefits, quality of life, gender, and agricultural practices, was modeled to find answers to low productivity; this was achieved through the application of descriptive statistics [15].

In a comparative study called "*Aumento de la productividad del cacao en Costa de Marfil, Ghana, Indonesia y Colombia*," proposed by Mejia [16], a semilogarithmic yield model with time series and panel data was applied to perform predictive analysis with linear regression models [16]. It was concluded that the educational achievement of the farmers and their experience in cacao farming were determining factors for efficiency [17]. One of the main precedents that contributed to the proposal on managing economic sustainability presented here is found in [18].

There, researcher Gabriela Sánchez Fernández developed a methodology to evaluate the sustainability of dryland farming in the plains of Castilla y León and irrigated farming in the Duero Valley in Spain. She based on the calculation of 16 agricultural sustainability indicators covering three components of the concept (economic, social, and environmental) and their synthesis into 9 different types of agricultural sustainability, using various techniques of weighting and aggregation of indicators [18].

Based on the previous literature review, a foundational definition for managing economic sustainability was proposed in terms of the outcome of applying strategies for the use of available resources in the cacao system, which allows increasing benefits through productivity and profitability [19]. This includes criteria for: production (P), as the capacity to use the best option to obtain the highest possible level of products, using certain supplies [20]; management (M), the producer's action to achieve organizational rationality, resulting from both productive and non-productive activities [21]; and commercialization (C), as the dimension of power, to produce distributive outcomes through price setting, given the interaction of farmers in transactions with clients and suppliers [22].

From the perspective of an economically viable agricultural development, centered on the farmer, cacao farming, and the market, the main research objective proposed is to construct a theoretical model for small cacao producers to ensure economic sustainability, based on the criteria of production, management, and commercialization.

2. Materials and Methods

A deductive methodology with an agrarian economy approach was employed [23], starting from the literature review and the creation of an analytical matrix model with contributions from experts and surveyed cacao producers. To carry out the scientometric analysis, the selected database was Scopus 2023, framed in the period from 2012 to 2022, with an equation constructed under Boolean Logic [24]. This phase facilitated the identification of a set of variables and economic sustainability indicators, prioritized by 14 cacao experts, initially using the Vester matrix approach [25].

Subsequently, the simple indicators were defined in accordance with parameters from the hierarchical structure derived from the SAFE Framework (*Sustainability Assessment of Farming and the Environment*) and the PC&I Theory (Principles, Criteria, and Indicators) [26].

For the standardized selection of economic sustainability indicators and their relative weights, the analytical hierarchical process (AHP) methodology and Saaty fundamental scale [27] were applied, formula (1).

$$\mathbf{A} = [a_{ij}] \begin{vmatrix} 1 & a_{12} \dots. & a_{1j} \\ a_{21} & 1 \dots. & a_{2j} \\ \dots.. & \dots.. & \dots \\ a_{i1} & a_{i2} & 1 \end{vmatrix} \quad (1)$$

Where:

A = Saaty Matrix
a_{ij} = Relative Importance of the criterion (or sub criterion) i on the value or sub criterion j.

This multicriteria technique allowed selecting and assigning relative weights to eleven (11) indicators, in a process that underwent three stages: 1) modeling, 2) valuation, and 3) prioritization and synthesis, with the support of an instrument applied in an expert panel [28]. In the selection, the consistency of the experts in making judgments was considered, using the consistency ratio (CR) criterion <0.10 [29], and the development of the normalized matrix N_{nxn} proceeded.

For the empirical validation of the theoretical model, 228 surveys were applied to an equal number of cacao producers, resulting in a data matrix, which was normalized using the min-max technique. Subsequently, the aggregation stage was conducted [18]. In this procedure, ratings were assigned so that the maximum and minimum values of the indicators are shifted to the values 0 and 1 respectively, as shown in formula (3).

$$N_{(Xq)} = \frac{Xq - \text{Xmin}}{\text{Xmax} - \text{Xmin}} \; ; x_q < \text{xmax} \quad (3)$$
$$; x_q \geq \text{xmax}$$

Where,
$N_{(Xq)}$: Normalization Function
X_q: Current value of indicator q
X_{max}: Maximum observed value of indicator.
X_{min}: Minimum observed value of indicator.

The scaling process for correlation analysis starts with the simple average at the variable level, simple average at the indicator level, weighted average at the sub-criterion level, and weighted average at the criterion level. For the interpretation of the results, the scale suggested by [30] was adapted, proposing an order to evaluate the economic sustainability of small cacao producers, as shown in Table 1.

Table 1. Sustainability classification scale

CLASS OF ECONOMIC SUSTAINABILITY	SCALE
Very High Economic Sustainability	0.80 – 1.00
High Economic Sustainability	0.60 – 0.79
Moderate Economic Sustainability	0.40 – 0.59
Low Economic Sustainability	0.20 – 0.39
Very Low Economic Sustainability	0 – 0.19

The data were structured into a matrix of size (92x228), arising from the encoding of responses to 48 questions that make up the utilized instrument. The data were processed electronically using statistical techniques for aggregating variables and indicators and for normalization, utilizing the statistical package Stata version 17. The min-max normalization was chosen, as it was considered the more aligned with the intended purposes, because it seeks to minimize the maximum existing deviation.

The mathematical formula and the multiple linear regression equation representing the ESM model enabled the analysis of the relationship between variables and establishing the dependence between a continuous outcome and the predictors, applying descriptive statistical techniques [31]. Since the predictors can be continuous, categorical, or derived fields, nonlinear relationships were also supported. Criteria of normality, homoscedasticity, and multicollinearity are confirmed. The predictors comply with independence and without evidence of autocorrelation. This indicates that the model is appropriate and meets the challenge of integrating into a synthetic indicator of economic sustainability, the criteria of production, management, and marketing.

3. Results and Discussion

This section presents the scheme that explains the reliability and consistency in the measurement and verification of the proposed model.

3.1. Results

A predictive model was created to evaluate the management of economic sustainability "ESM" for small cacao producers, structured in close relation to the management of agricultural and commercial practices as shown in Figure 1. This model is proposed as a useful tool for decision-making by producers and institutions.

The GSE model constitutes an information system that integrates the criteria of production (P), management (G), and marketing (C), for commercial agriculture such as cocoa. It is conceived as a business, with minimum viable results in productivity and marketing, to guarantee financial profitability that improves the level of development of producing families [32].

The predictive property of the model guides the correct decisions for economic sustainability, mediated by a synergy that involves the attitude and motivation of the farmer and their family environment, towards better productivity outcomes [31].

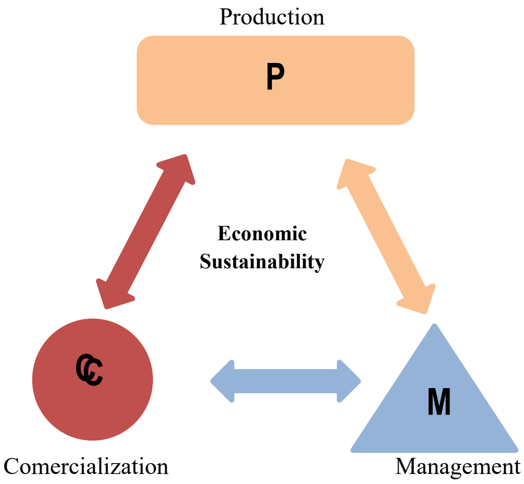

Figure 1. ESM Operative framework

Motivated producers who learn new procedures or techniques are more likely to achieve better results in their work. Learning leads to good decisions in crop maintenance, post-harvest processes, commercialization, and the quantity and quality of cacao beans to offer and sell.

The model is significant because it provides science with a different and functional criterion to measure, monitor, and evaluate economic sustainability in agriculture, at the level of cacao production systems [33].

The identified variables were prioritized using the Vester incidence matrix, and the standardized selection of basic indicators was carried out through the analytical hierarchy process (AHP) and Saaty scale (1987).

Subsequently, weights per criterion and sub-criterion were calculated, which were integrated into the estimation stage of the indices, using tools of descriptive, binomial, and multivariate statistics, as presented in Table 2.

Table 2. Weighed indicators

ECONOMIC SUSTAINABILITY INDICATORS	%
P1: Crop Yield Efficiency (CYE)	12.0
P2: Crop Age (AGE)	12.0
P3: Implementation of Technology packages (IMPLTEC)	8.0
P4: Post Harvest Process Assurance (PHPA)	8.0
Production (Total)	40.0
G1- Social Capital (SOCIALC)	7.6
G2: Management Plan (MPLAN)	11.4
G3: Capacity to Generate Employment (CGEM)	3.8
G4: Producer Financial Profitability (PROFIPRO)	11.4
G5: Risk of Abandonment of the Cacao Activity (RACA)	3.8
Management (Total)	38.0
C1: Transaction Costs (TRANSCO)	8.8
C2: Bargaining Power (BAPO)	13.2
Commercialization (Total)	22.0
Total	100.0

Based on the weighted results, a basic mathematical model was built, which allows understanding the underlying ideas in the proposed model and is synthesized in formula (4):

$$Y(GSE_i) = \mathrm{k} + P_i * 0.4\% + C_i * 0.22\% + G_i * 0.38\% + e_i \quad (4)$$

Where:

$Y(ESM_i)$ = dependent variable, understood as the outcome of the implementation of the model.
K = intercept, the value for the point $(0, y_i)$
P = Production independent variable with a relative weight of 40%.

C = Commercialization independent variable with a relative weight of 22%.
M = Management independent variable with a relative weight of 38%.
e_i = Error

Next, the model is represented at the level of the independent variables.

- **The Production variable expressed in formula (5) as follows:**

$$Y(P_i) = \mathrm{k} + AGE_i * 0.12\% + CYE_i * 0.12\% + IMPLTEC_i * 0.8\% + PHPA_i * 0.8\% + e_i \quad (5)$$

Y(Pi)= Production dependent variable

K = intercept value for point $(0, y_i)$.

Age = Crop age independent variable with a relative weight of 0.12.
CYE = Crop yield efficiency independent variable with a relative weight of 0.12.

IMPLTEC = Implementation of Technology Packages independent variable with a relative weight of 0.8.

PHPA = post-harvest process assurance independent variable with a weight of 0.8.

e_i= Random errors

- **Management Variable: identified with formula (7)**

$$Y(M_i) = k + SOCIALC_i * 0{,}76 + MAPLAN_i * 0{,}114 + CGEM_i * 0.38 + PROFIPRO_i * 0{,}114 + RACA_i * 0.38 + e_i \quad (7)$$

$Y(M_i)$ = Management dependent variable

K = intercept value for the point (0, y_i).

SOCIALC = Social Capital independent variable with a relative weight of 0.76.

MAPLAN: Plan independent variable with a relative weight of 0.114.

CAGEM: Capacity to Generate Employment independent variable with a weight of 0.38.

PROFIPRO: Financial Profitability independent variable with a relative weight of 0.114.

RACA \): Risk of Abandoning Cacao Activity independent variable with a relative weight of 0.38.

e_i = Error

- **Commercialization Variable: as recorded in formula (6).**

$$Y(C_i) = k + TRANSCO_i * 0.88\backslash\% + BAGPO_i * 0.132 \% + e_i \quad (6)$$

$Y(C_i)$ = Commercialization dependent variable
k = intercept value for the point (0, y_i).

TRANSCO = Transaction Costs independent variable with a relative weight of 0.88%.

BAGPO = Bargaining Power independent variable with a relative weight of 0.132.

e_i = Error

The study shows that there is a greater presence of moderately sustainable production systems, as well as opportunities to improve productivity up to break-even point levels or higher.

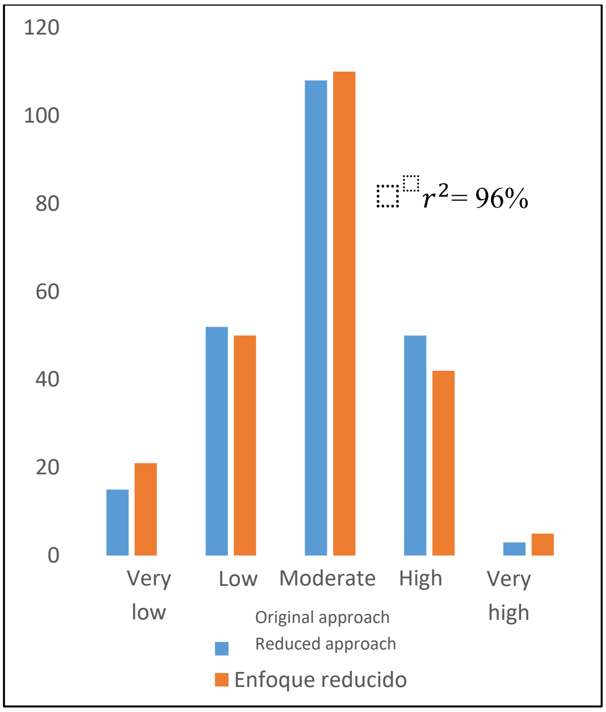

Figure 2. ESM Index in small cacao plantations in Huila

Cronbach's alpha coefficient (α) was used to measure the reliability of the measurement scale and the selection of variables that do not contribute to each dimension. A new index with a reduced focus was determined, to contrast it with the one calculated under the original model. It was proven that the model under the theoretical and reduced approach does not show significant variability, demonstrating the robustness of the ESM model, as represented in Figure 2.

3.2. Discussion of Results

With this analytical and deductive approach, the central objective of understanding the economic sustainability of small cacao plantations was achieved by verifying production, commercialization, and management criteria against viable minimums, with empirical validation from a case study in the Huila department - Colombia.

From the anthropocentric perspective, focused on the farmer and the crop, the methodology contributes objective information to improve the measurement, monitoring, and evaluation of economic sustainability in the cocoa sector.

The analysis of the data yielded empirical validation, allowing the definition of a functional linear regression model to predict future results according to the behavior of the independent variables [31]. The axes in the agri-food supply chains to which cocoa belongs define requirements to be met in terms of quality, quantity, logistics, and negotiation strategies for setting prices, represented in the independent variables [34].

From this theoretical perspective of a vision focused on the farmer and the crop, the methodology can contribute to improving the current guidance for calculating the economic sustainability of the cacao sector and the development of public policy guidelines for rural growth and development, based on the use of objective information.

The results show us a reality of difficulty faced by most small cacao producers, which can be predicted and corrected in advance with the implementation of the ESM model. The current reality indicates that 6.58% of the plantations have very low sustainability, 22.81% have low sustainability, 47.37% are moderately sustainable, 21.93% have high sustainability, and 1.32% have very high sustainability as observed in Figure 2.

This study tested the functional capacity of the ESM model, allowing for the inference of the possibility to surpass the current results of economic sustainability and to increase productivity. The use of the correlation matrix between resultant independent variables allowed finding a low correlation between independent variables and the existence of correlation with the dependent variable (ESM) observed, as recorded in Table 3.

Table 3. Economic sustainability management model (ESM)

	Estimate	Std. Er	Value t	Pr (>|t|)
Intercept	39.0851	0.6123	63.83	<2e-16
Product.	-0.8801	0.0218	-40.26	<2e-16
Commerc.	-0.8287	0.0278	-29.79	<2e-16
Manag.	1.36616	0.0263	<2e-16	

The observed dependent variable ESM was calculated from the equation of productivity as an independent variable, entering to measure its contribution in improving the proportion of variability, under formula [8].

$$Y_{(ESM\ observed)} = \frac{\text{kilos produced in the last year}}{(\text{hectares of cacao} * \text{number of trees per hectare}) * 100\%} \quad (8)$$

Based on the matrix of estimated coefficients from Table 3, the mathematical equation of the economic sustainability management model for small cacao producers in Huila (ESM) is constructed under formula 9:

$$Y(\text{GSE observed})_i = 39{,}08 - (0{,}88 * P_i) - (0{,}82 * C_i) + (1{,}36 * M_i) + e_i \quad (9)$$

The model, with all variables introduced as predictors, has a high R^2 (0.9517), capable of explaining 95.17% of the variability observed in productivity. It is also observed that for each unit increase in the management predictor, the farm productivity increases by an average of 1.36 units, keeping the other predictors constant. In the modeling, 299 observations were worked with, which complies with what is observed to prevent a variable from appearing influential when it is not [35].

The model p-value criterion is significant (2.e-16), so it is accepted that it is not by chance; at least one of the partial regression coefficients is different from 0 [35]. In this way, those responsible for managing the economic sustainability of cacao can predict the dependent variables based on the independent variables and establish the dependence between a continuous outcome and the predictors.

Likewise, when comparing the results in the ESM modeling (theoretical) versus ESM (observed), it indicates that the proposal created from the theoretical model and experts has a superior prediction to the performance evaluation concerning what is observed on the farms in the Huila department.

The productivity indicator is in the range of 0% and less than 40% of the break-even point, as observed in the box plot of Figure 3.

The observed dependent ESM variable was calculated using the productivity formula (8) as an independent variable, measured on a scale of [0 - 100]. The results indicate that there is a futuristic scenario of opportunities for the growth of the cacao production system in Huila, between 40% and 60%.

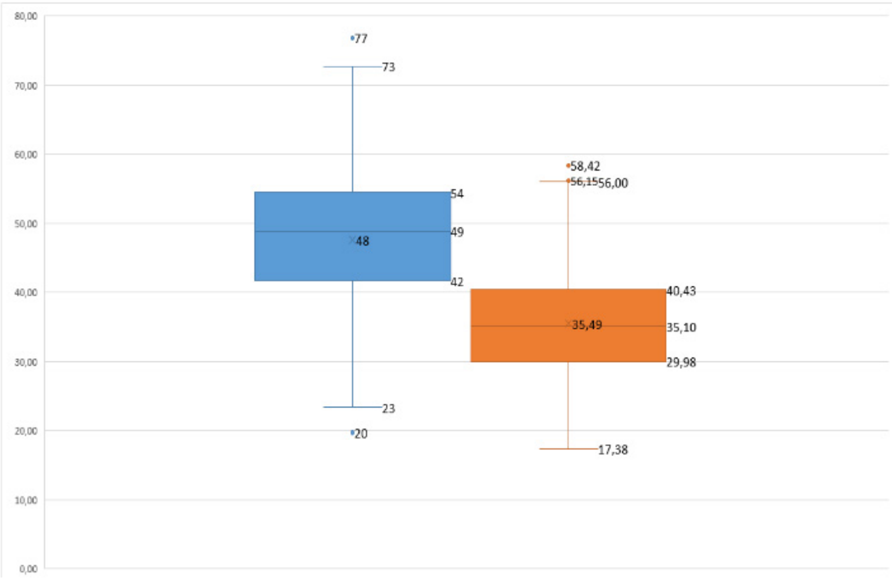

Figure 3. Comparative diagram of ESM (model) and ESM (observed)

It can be inferred that the small cacao plantation in Huila is characterized as a business with low economic investment and minimal expenses, which subsists with low yields, creating opportunities to increase productivity outcomes and ensure long-term economic sustainability. The present model involves the implementation of viable practices by the producer, in capital investment, agronomic culture, and bargaining power, where cacao is the focus.

4. Conclusion

The proposed model successfully measures the economic sustainability of small cacao production systems, using a network of indicators that simplified the complexity of economic sustainability. It is a useful tool for generating information for predictive decision-making by cacao producers and institutions within this subsector.

The information obtained with the ESM model can guide technical teams in data selection, the search for predictive patterns, and support in interpreting economic sustainability in cacao production systems, which validates the model for its use in simulating possible futures.

Due to its validity and reliability, it can be an instrument guiding the implementation of public policies to improve the profitability of the agricultural business in the Huila department.

As an analytical tool, the model offers decision alternatives to advance cultural practices at the costs demanded by market requirements and respond to commercialization challenges in a globalized economy. Those responsible for applying the ESM model must have strategies like selling the product by quality and not by quantity, aligned with productivity and profitability objectives.

The most significant practical limitation for implementing the ESM model is related to the cultural practices of farmers in technification, producing, and selling cacao. Farmers must view their plantations as an agribusiness that provides an income capable of contributing to the satisfaction the material and spiritual needs of their families.

The model considers corporate culture as the driving force behind change, to ensure economic sustainability. Continued programs of education, association, and solidarity enhance the behavior to evolve from peasant agriculture to an agrarian and business-oriented cacao culture.

Greater creativity, productivity, quality, innovation, and bargaining power are anticipated with the implementation of the ESM model.

Finding new approaches to constructing economic sustainability indexes that use normalization, weighting, and aggregation techniques different from those selected in this work are subjects for future studies and research.

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