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Structured Equations to Assess the Socioeconomic and Business Factors Influencing the Financial Sustainability of Traditional Amazonian Chakra in the Ecuadorian Amazon

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Abstract: This study focuses on investigating the dimensions of sustainability and their influence on financial-economic sustainability (FES) in traditional agroforestry systems (TAFS) using the case of the Amazonian Chakra. The main objectives were to analyze the dimensions of sustainability and to establish the causal relationships between these dimensions and the FES. To carry out this research, 330 households in Napo Province that use the Amazonian Chakra system to grow cocoa were selected in order to analyze the relationship between the different dimensions of sustainability and FES in this unique context. The results of the study show that practices related to food security (FS) and business factors (BF) have a positive and significant impact on the FES of cocoa-producing households in the Amazonian Chakra system. These findings support the importance of ensuring the availability and quality of food and promoting responsible business practices in these environments. In contrast, the dimensions of environmental resilience (ER) and biodiversity conservation (BC) showed a negative impact on FES, highlighting an economic-financial imbalance in relation to conservation and environmental resilience actions in the Amazonian Chakra. This study contributes to the knowledge needed to promote agricultural practices that include an equal focus on FES, biodiversity conservation, and environmental resilience practices in a globally significant area, providing valuable information for the design of sustainable agricultural policies and practices in the Amazonian Chakra.

Keywords: cocoa; Amazonian Chakra; structural equation model (SEM); SAFA

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1. Introduction

Sustainability contributes to ensuring long-term food production by linking natural resources with their use and management [1–3]. Therefore, it is of great interest to deepen our understanding of the relevant variables in stakeholders' decision-making concerning sustainability, such as the socioeconomic, organizational, and external factors influencing the sustainability of their operations [4,5].

The assessment of sustainability is developed through a set of indicators implemented in agricultural, forestry, and livestock projects [6]. The agrosystem evaluation framework encompasses a cyclical, adaptable, and practical structure with a participatory, interdisciplinary, and comprehensive approach, facilitating the identification of the intersection of environmental, social, and economic processes involved in sustainability [7–9].

Currently, various methodologies exist for measuring agricultural sustainability, such as response-inducing sustainability evaluation (RISE) which assesses agricultural sustainability in three dimensions: environmental (30 parameters across 6 indicators), social (10 parameters across 2 indicators), and economic (11 parameters across 2 indicators), covering everything from land use to farm management [10,11]. The sustainability assessment of farming and the environment (SAFE) is a holistic methodology with a hierarchical structure that consists of principles, criteria, indicators, and reference values. The principles are related to the multiple functions of the agroecosystem [12], indicateurs de durabilité des exploitations agricoles or farm sustainability indicators (IDEA) which consists of approximately 41 indicators, distributed across the three dimensions of sustainability: Economic Dimension: about 12 indicators. Social Dimension: around 8 indicators. Environmental Dimension: approximately 21 indicators [13], monitoring tool for integrated farm sustainability (MOTIFS) it assesses agricultural sustainability across three levels, with scores ranging from 0 to 100, covering economic, ecological, and social aspects to identify areas for improvement [14,15]. The system for environmental and agricultural modeling; linking European science and society's (SEAMLESS) goal is to develop a framework that underpins the integrated assessment of agricultural systems on multiple scales (from the field, farm, region up to the EU and the world) [16,17]. Multi-criteria decision analysis (MCDA) provides a simple, inexpensive, yet holistic tool for assessing the sustainability level of agricultural systems. The multi-attribute utility theory is utilized [18,19], the evaluation of natural resource management systems incorporating sustainability indicators (MESMIS) which proposes integrating information on the interaction of system components to identify the effects of social, economic, and environmental processes at different scales. Sustainable agroecosystems must meet attributes of high productivity, stability, adaptability, autonomy, and equity [20,21], and the sustainability assessment of food and agriculture systems (SAFA) [22].

Evaluating the sustainability level of diverse agrosystems is of significant interest, both academically and practically. This process is carried out with the purpose of quantifying the causal relationships between various indicators. An outstanding example of such an assessment can be found in a study that reports the influence of financial indicators on the sustainability of the cereal-sheep dairy production system in Castilla La Mancha, Spain, where the structural equation model (SEM) was utilized [23].

SEM is a robust tool for analyzing the relationships of dependence between variables [24,25]. Unlike other techniques, such as multiple regression and factor analysis [26], SEM stands out for its ability to evaluate relationships between unobservable constructs, called latent variables, which can only be measured through observable variables. This allows for the control of the measurement error specific to each variable, which is crucial for assessing the validity of the measured constructs [24].

In this research, causal relationships were analyzed between different dimensions of sustainability: (a) environmental resilience (ER), (b) biodiversity conservation (BC), (c) food security (FS), (d) social factors (SF), and (e) business factors (BF) on the financial-economic sustainability (FES) of the agroforestry cocoa production system (Theobroma cacao), namely the Amazonian Chakra, a traditional agroforestry system (TAFS). The Chakra is an ancestral system used and preserved for millennia by the Kichwa population in the Ecuadorian Amazon [27,28].

For this analysis, 60 indicators selected from the SAFA tool were used to evaluate their performance in 330 cocoa-producing households that employ the Amazonian Chakra system in the Ecuadorian Amazon region (EAR), and to delve into the relationship between sustainability indicators and their influence on the economic and financial stability of these rural producers. The results were analyzed using partial least squares structural equation modeling (PLS-SEM).

The structure of the article begins with an introduction to the Amazonian Chakra, followed by a focus on the SAFA methodology applied to cocoa producers in Amazonian Chakras and the EAR. The materials and methods section describes the formulation of the hypotheses, methodology, data sources, sample design, and data collection instrument. The results of the model validation are presented in the corresponding section. Finally, the discussion and conclusions sections analyze the findings and their implications in comparison to the data from the literature review.

1.1. Context of the Traditional Agroforestry System: The Amazonian Chakra

Tropical agroforestry systems are distinguished by significantly higher levels of biodiversity and sustainability compared to other intensive systems [29]. These systems attain a greater degree of sustainability when they incorporate shade trees comprising approximately 40% of the composition within landscapes that encompass forest remnants [30,31]. In this framework, the Amazonian Chakra deeply aligns with various sustainable development goals (SDGs) [32,33]. In this holistic context, the Amazonia Chakra represents a potential for achieving several of the 17 SDGs. The Chakra enables self-sufficiency in food, medicinal products, and construction materials, ensuring household income, presenting a sustainable alternative that promotes poverty reduction (SDG 1), fostering food security and sovereignty (SDG 2) [34], enhancing household incomes (SDG 8) [35], playing a key role in climate change mitigation (SDG 13) [36], and biodiversity conservation (SDG 15) [37], emphasizing its contribution to access to clean water and responsible production and consumption practices (SDGs 6 and 12).

From a socioeconomic and financial perspective, the majority of small-scale farmers who cultivate 70% of the cocoa in the lowland tropical regions of Latin America, West Africa, and Indonesia earn less than $2 a day but rely on cocoa production for between 60 and 90% of their income [38,39].

The Amazonian Chakra was recognized by the Food and Agriculture Organization of the United Nations (FAO) in February 2023 as a Globally Important Agricultural Heritage System (GIAHS). Under this recognition, the *"Amazonian Chakra is a productive area on family-managed farms with a focus on organic sustainability and biodiversity, valuing ancestral wisdom. These systems, rich in biodiversity and culture, benefit communities by ensuring food security, providing ecosystem services, preserving cultural values, promoting social cohesion, and conserving a highly biodiverse landscape"* [6].

Fine and flavor cocoa producers using the Amazonian Chakra system have farms averaging 8.4 hectares, with 2.2 hectares devoted to the cocoa Chakra system, 5.7 hectares to forests, and 0.4 hectares to other crops. The same authors mention that, on average, families consist of 5.2 members, 59% of them have female heads of household, and the average age is 48.7 years. 88.4% of them belong to the Kichwa Amazonian ethnic group and have completed an average of 7.5 years of education [40].

On the other hand, the Amazonian Chakra system plays a vital role in ensuring the cultural identity and food security of the Kichwa Amazonian population [27,41,42]. Despite limited financial resources, households practicing the Amazonian Chakra system, according to [37], do not go hungry. These researchers found that, on average, the Amazonian Chakra system provides 2091 Kcal per person per day, considering only the crops of the system and excluding tree fruits, small-scale livestock, and hunting and fishing activities in nearby rivers and forests.

It is increasingly recognized that this system is characterized by its high agrodiversity, integrating timber trees, fruit trees, palms, staple crops (mainly yuca and plantains), and, more recently, commercial crops (mainly cocoa and coffee), as well as medicinal and spiritual plants [43–46]. Moreover, for some of these producers, their main income comes from the Amazonian Chakra, especially those with greater access and integration into the market [47,48]. For instance, for producers targeting the fine and flavor cocoa market, the average monthly income from the Chakra is $558.04 (USD), representing 31% of their total income, and only 8% have access to credit [40].

1.2. Conceptual Framework: The SAFA Approach

The sustainability assessment of food and agriculture systems (SAFA), developed by the Food and Agriculture Organization of the United Nations [22], consists of three key components. First, there are guidelines that explain the sustainability principles used in the development of SAFA. Second, a detailed list of 116 sustainability indicators is presented, covering 58 subtopics, 21 themes, and 4 sustainability dimensions. Third, there is software provided for analyzing and presenting the results, which describe the sustainability of the evaluated system through a polygon organized into 21 themes and five levels of sustainability, ranging from "unacceptable sustainability" in red to "optimal sustainability" in dark green [49].

The SAFA is a fundamental tool for understanding the sustainability of food and agricultural production systems, which is of great importance in the search for more sustainable and resilient alternatives. The combination of guidelines, indicators, and software allows for a detailed and rigorous analysis of the systems under evaluation, facilitating the identification of strengths, weaknesses, and improvement opportunities [50].

Furthermore, the SAFA framework is internationally recognized as a reference for assessing the performance of agri-food companies in terms of sustainability, with the aim of supporting the implementation of sustainable and effective management in the agri-food sector [51]. In this study, this tool will be used to comprehensively evaluate the sustainability of agricultural operations to identify improvement opportunities and promote sustainable management in the agri-food sector [52,53].

2. Materials and Methods

2.1. Study Area

This research was conducted among 330 cocoa producers operating within the Amazonian Chakra system (Figure 1) in a region of high importance due to its culture and biodiversity. This area encompasses significant protected areas, including the Sumaco Napo-Galeras National Parks, Llanganates National Park, Colonso Chalupas Biological Reserve, Antisana Ecological Reserve, and the Sumaco Biosphere Reserve (SBR). The SBR was declared a biosphere reserve in 2000 by the United Nations Educational, Scientific and Cultural Organization's (UNESCO) Man and the Biosphere (MAB) program and is in Napo Province.

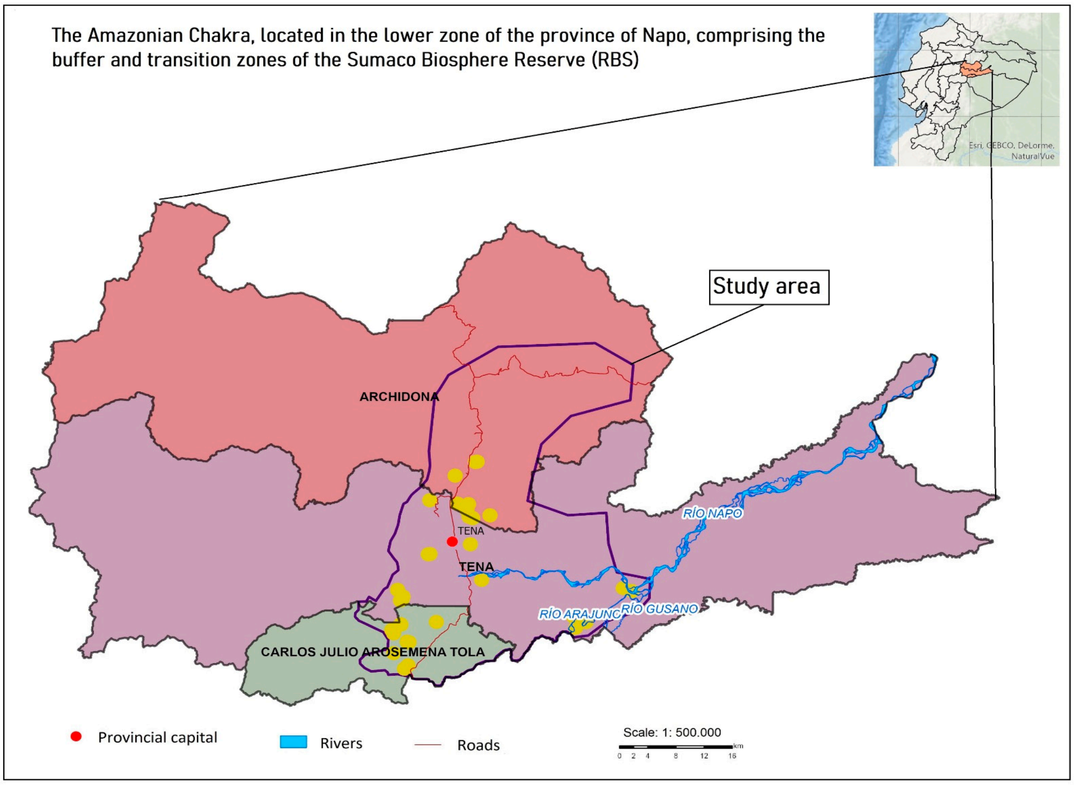

Figure 1. Study area, locations of households producing cocoa using the Amazonian Chakra system.

This region has been inhabited for millennia by indigenous populations, specifically the Kichwa Amazonian people, who were colonized around 400 years ago. It is considered a biodiversity hotspot under severe threat [54]. According to UNESCO guidelines, buffer and transition zones of a biosphere reserve should promote biodiversity conservation, sustainable development, education, and research as a means of reconciling humans and nature [55].

2.2. Research Design

For this study, the SAFA sustainability assessment method was used [56], containing 116 indicators. Through a detailed evaluation by a panel of 15 sustainability experts from the Amazon region, we selected 60 indicators particularly relevant for analyzing the specific Amazonian context. This selection focused on those socioeconomic and business aspects crucial for determining the economic and financial sustainability of chakras. The selection process was based on unanimous agreement among the experts, ensuring that each chosen indicator directly reflects the most significant socioeconomic and environmental elements impacting the sustainability of the region [57].

We applied a questionnaire derived from the selected indicators to a stratified random sample of 330 households from three rural associations dedicated to cocoa production within the Amazonian Chakra System. This procedure allowed us to obtain a detailed overview of sustainability practices and the current challenges in the Chakra system, thus ensuring a comprehensive and up-to-date understanding of the economic and financial sustainability dynamics in these agricultural systems.

Subsequently, the partial least squares structural equation modeling (PLS-SEM) with latent variables and a path model approach was employed [58]. This method was chosen for its ability to handle multiple constructs represented by variables not directly observable but inferred through the selected indicators. The constructs were represented by latent variables that are not directly observable but are inferred through the selected indicators for each of them [59]. We opted for the PLS-SEM model with latent variables as it facilitates the identification of relationships between the constructs and their respective indicators. This approach provides a more in-depth and comprehensive perspective on the interactions within our study.

Furthermore, conducting an SEM analysis of the data involves both measurement and structural models [60]. This method was selected for its ability to manage multiple constructs represented by variables not directly observable but inferred through the chosen indicators. Thus, the necessary statistics were obtained to determine the degrees of correlation between the independent and dependent variables. WarpPLS 8.0 software was used to explore the statistical relationships between the constructs and ascertain how socioeconomic and business factors impact financial-economic sustainability in traditional agroforestry production systems.

To ensure the validity and reliability of the model, model quality indicators of PLS, such as the R^2 of endogenous constructs, item loading values, and the significance of the model paths were evaluated through bootstrapping with 5000 subsamples. This methodological approach not only highlights the analytical precision of the study but also deepens the understanding of the key interactions defining the sustainability of the chakras under study.

2.3. Sustainability Indicators Survey

As demonstrated in Figure 2, the process occurred in two stages. In the first stage, key sustainability indicators for the Amazon rural context were identified through a workshop involving 15 expert researchers and stakeholders engaged in sustainable development projects. During the workshop, the SAFA questionnaire was analyzed, and the relevance of each question in relation to the local context was assessed. This process led to the selection of the final 60 questions for the questionnaire. The most representative and context-appropriate questions for the Amazon region were chosen by consensus. Subsequently, they were grouped into homogeneous constructs to gain a deeper understanding of their relationships and their impact on the obtained variability. Experts evaluated each question on a Likert scale from 1 to 5 [61]. In the first round of evaluation, questions that received a maximum score (five) from nine or more experts were selected, while those that received the minimum score (one) from nine experts were discarded.

To obtain the concordance index, the Ishikawa index based on the level of agreement among experts was applied, as described in other studies [62,63]. The index compares the responses provided by each expert to each question in the SAFA questionnaire, thereby assessing the level of agreement among them. Calculating the proportion of experts who agree on each response results in a concordance value for each question. Subsequently, questions with a concordance level exceeding 60% and an average score above 3.5 were selected. This threshold of concordance was chosen to ensure that the selected questions had a high level of agreement among experts. The average score was used as an additional indicator of the quality of the selected questions.

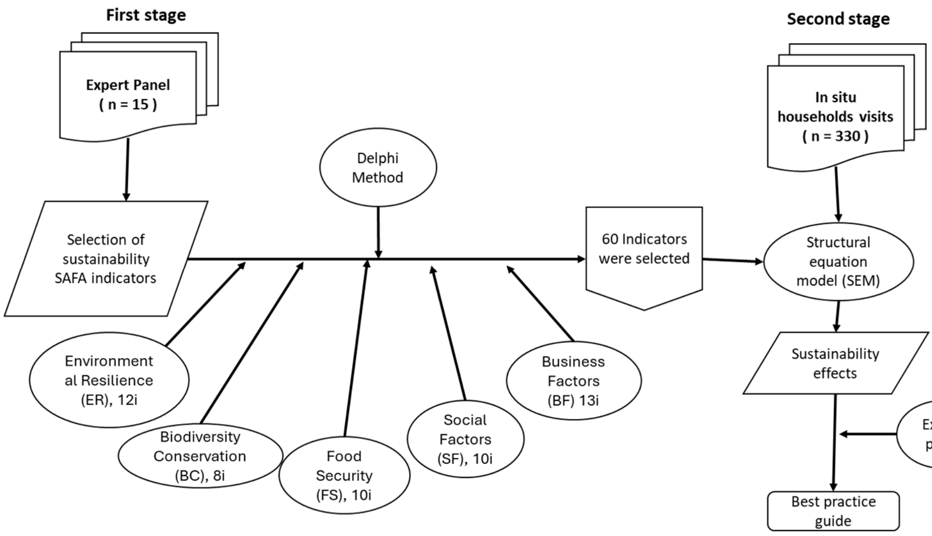

Figure 2. Research steps.

2.4. Hypothesis Approach

The main hypothesis is that sustainability indicators have a positive influence on the economic and financial performance of the Amazonian Chakra system. The structural model for the relationship between sustainability indicators and outcomes is depicted in Figure 3. This hypothesis aims to examine the direct effect of five sustainability indicators, using economic and financial results as the dependent variable.

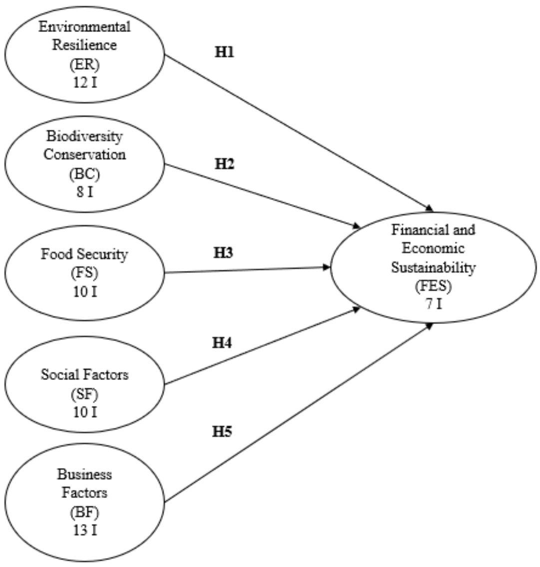

Figure 3. Theoretical framework and hypothesis from H1 to H5.

Six latent variables or constructs were defined: five constructs as sustainability indicators and one as the economic and financial performance of the Chakra. Initially, the percentages of farmers who complied with the indicator for each latent variable were calculated, allowing us to determine the characteristics of the studied Chakra [56].

Appendix A provides a summary of the constructs and indicators related to sustainability in a study involving a total of 330 participants. The constructs include environmental resilience (ER) [64,65], biodiversity conservation (BC) [66], food security (FS) [67,68], social factors (FS) [69,70], business factors (BF) [71], and financial and economic sustainability (FES). Each construct is accompanied by various indicators that measure specific aspects related to sustainability. The numerical values associated with each indicator reflect the average ratings given by the participants, offering information on the perception of sustainability in each of these areas within the study's context.

To assess the impact of sustainability dimensions on the FES of a traditional agroforestry production system, the Amazonian Chakra, an empirical analysis was formulated with five hypotheses, as depicted in Table 1.

Table 1. Hypotheses and dimensions of sustainability.

Hypotheses to Evaluate the Causes of Financial-Economic Sustainability
Hypothesis 1. *Sustainability indicators related to environmental resilience have a positive impact on financial-economic sustainability in traditional agroforestry production systems.*
Hypothesis 2. *Sustainability indicators related to biodiversity conservation have a positive impact on financial-economic sustainability in agroforestry production systems.*
Hypothesis 3. *Food security practices in agroforestry production systems have a positive impact on financial-economic sustainability.*
Hypothesis 4. *Social factors in agroforestry production systems have a positive impact on financial-economic sustainability.*
Hypothesis 5. *Business factors (BF) have a positive impact on financial-economic sustainability in agroforestry production systems.*

2.5. Statistical Analysis

PLS-SEM (partial least squares—structural equation modeling) was employed to measure the impact of sustainability indicators on the final performance of the Amazonian Chakra. The estimation of the structural model assessed the direct relationships between different constructs, using path coefficients, significance levels, and cross-validated redundancy [58]. Attention was given to the graphs without feedback loops between nodes, as presented in Figure 3. The model was estimated using WarpPLS 8.0 software.

First, the internal consistency of each construct was measured using Cronbach's alpha and composite reliability. Additionally, to strengthen the analysis, McDonald's Omega was used. Second, their convergent validity was assessed through indicator reliability and extracted variance, and, finally, the discriminant validity between indicators and latent variables was evaluated [72], as well as cross-loadings [73].

The causal relationships between sustainability dimensions and the performance of the Amazonian Chakra were measured in the second stage. To validate Hypotheses 1 to 5, structural equation models were estimated using PLS [74] with WarpPLS 8.0 software to test the relationships between indicators and latent constructs, as well as the hypothesized structural relationships between latent constructs [75]. The criteria for choosing the algorithm were based on the novelty of the phenomenon, its modeling being in an emerging stage, and compliance with the minimum PLS recommendations regarding sample size, prediction accuracy, and relatively low requirements for data multivariate normality [76].

3. Results

3.1. Causal Effects on Financial-Economic Sustainability

To test the posited hypotheses, a linear structural equations model with latent variables was defined and estimated. Figure 4 presents the results of the linear model of SEM, while Figure 5 reports the non-linear model. Figure 4 illustrates the causal effects among the studied variables along with their respective p-values. The arrows indicate the direction of the proposed relationships, and the ovals represent latent variables that embody the formulated constructs: environmental resilience (ER, 12 indicators), biodiversity conservation (BC, 8 indicators), food security (FS, 10 indicators), social factors (SF, 10 indicators), business factors (BF, 13 indicators), and financial and economic sustainability (FES, 7 indicators). The mean values for each indicator in the structural model constructs are described in Appendix A.

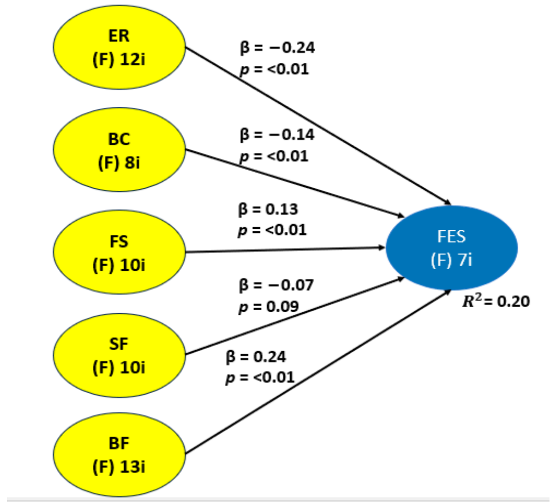

Figure 4. Research model scheme and main results.

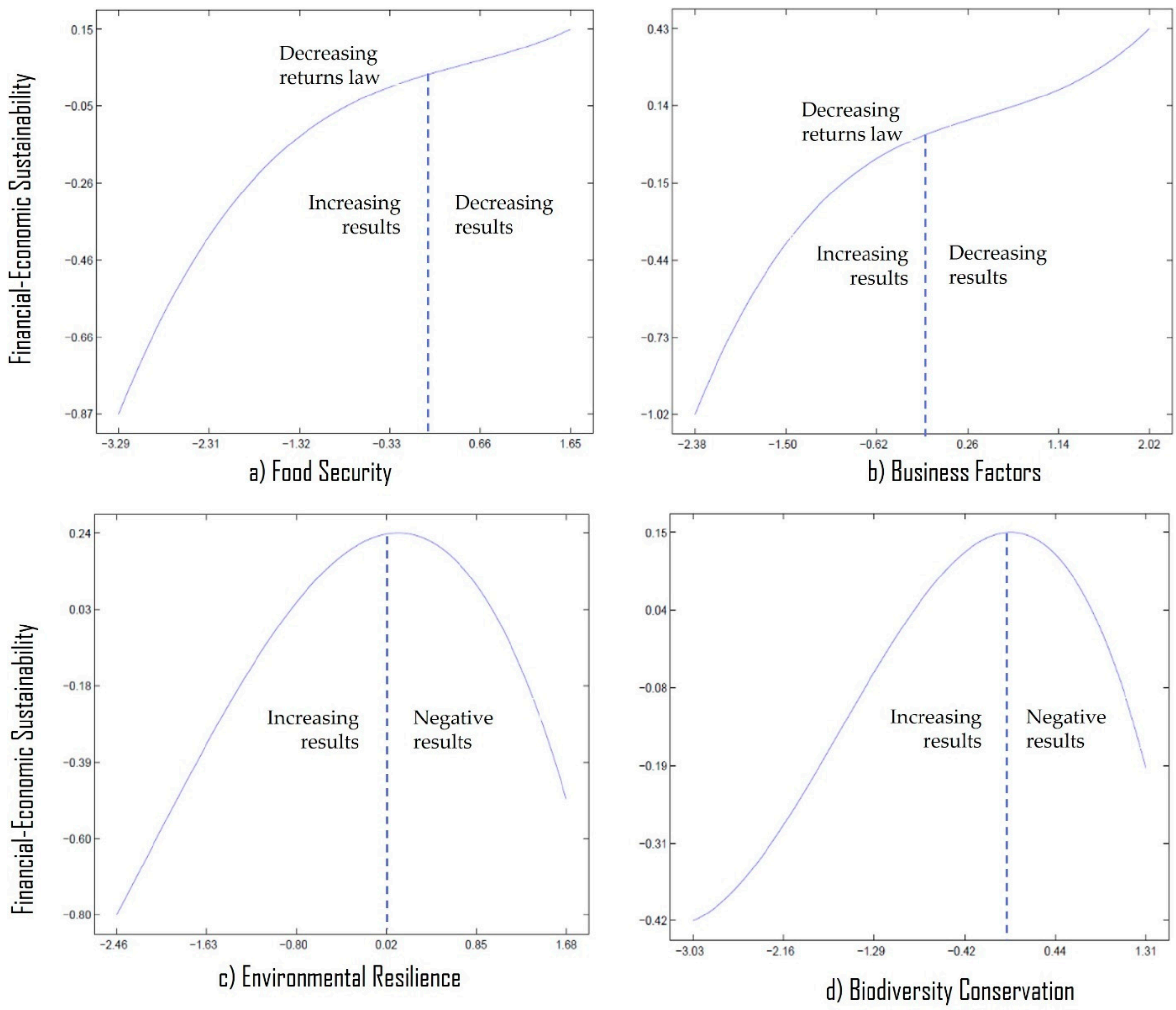

Figure 5. Utility curves of food security (FS), business factors (BF), environmental resilience (ER), biodiversity conservation (BC), and financial-economic sustainability (FES).

The path coefficients (beta) were normalized, ranging from −1 to 1, measuring the strength and direction of the relationship. The model was estimated using WarpPLS 8.0 software.

Table 2 summarizes the fit indices, model quality, and their interpretation. The following indices were used to test the hypotheses and assess the model fit [77]: average path coefficient (APC); average R-squared (ARS); average adjusted R-squared (AARS); average variance inflation factor of blocks (AVIF); average full variance inflation factor (AFVIF); Tennenhaus goodness of fit index (GoF); Sympson's paradox ratio (SPR); R-squared contribution ratio (RSCR); statistical suppression ratio (SSR); and non-linear bivariate causal direction ratio (NLBCDR). All quality indices met the recommended thresholds.

Table 2. Model fit and quality indices summary.

Index	Value	Value Interpretation
Average path coefficient (APC)	APC = 0.165, $p < 0.001$	Significant if $p < 0.05$
Average R-squared (ARS)	ARS = 0.200, $p < 0.001$	Significant if $p < 0.05$
Average adjusted R-squared (AARS)	AARS = 0.187, $p < 0.001$	Significant if $p < 0.05$
Average block VIF (AVIF)	AVIF = 1.322	Acceptable if ≤5, ideally ≤3.3
Average full collinearity VIF (AFVIF)	AFVIF = 2.329	Acceptable if ≤5, ideally ≤3.3
Tenenhaus GoF (GoF)	GoF = 0.307	Small ≥0.1, medium ≥0.25, large ≥0.36
Sympson's paradox ratio (SPR)	SPR = 0.800	Acceptable if ≥0.7, ideally =1
R-squared contribution ratio (RSCR)	RSCR = 0.958	Acceptable if ≥0.9, ideally =1
Statistical suppression ratio (SSR)	SSR = 1.000	Acceptable if ≥0.7
Non-linear bivariate causality direction ratio (NLBCDR)	NLBCDR = 0.700	Acceptable if ≥0.7

Table 3 presents the results of the hypothesis tests that assessed how sustainability indicators influence FES in traditional agroforestry production systems (in this case the Amazonian Chakra) based on cocoa cultivation. Two hypotheses are confirmed: the indicators related to FS practices and the influence of BF have a positive impact on FES, while ER and BC have a negative impact on FES. On the other hand, the hypothesis related to SF was rejected because no significant relationship ($p > 0.01$) was found, although it also showed a negative influence on the operating result.

Table 3. Direct effects and *p*-values.

	FES		Hypothesis	Model Results	Influence
	β	*p*-Value			
ER	−0.24	<0.01	1	Accepted	Negative
BC	−0.14	<0.01	2	Accepted	Negative
FS	0.13	<0.01	3	Accepted	Positive
SF	−0.07	<0.09	4	Rejected	Negative
BF	0.24	<0.01	5	Accepted	Positive

Accepted with *p*-value < 0.01 and Rejected for *p*-value < 0.05.

3.2. *Dynamics in the Patterns of Financial and Economic Sustainability*

Hypotheses 1 and 2 were accepted (Table 3). The constructs ER and BC showed a direct negative effect on the Chakra's results (FES), with coefficients of β = −0.24 and β = −0.14, respectively (Figure 4), and a significance level of 99%. The non-linear analysis provided a deeper understanding of these relationships (Figure 5c,d) [78]. The results suggest that ER and BC behave as a production curve. Chakras with very low environmental resilience and biodiversity conservation levels (from −2.5 to 0) tended to show increasing returns on the result variables, with a strong positive association between sustainability and the financial and economic indicators (ascending leg of the parabolic function). This relationship is inverted at high values of ER and BC (decreasing section of the parabolic function).

The linear estimation results showed that Hypotheses 3 and 5 were accepted (Table 3), where FS and BF have a direct positive influence on FES (β = 0.13 and β = 0.24, respectively). Figure 5 shows the relationships between sustainability and the resulting indicators. Figure 5a,b display non-linear results from the SEM model. The behavior of both variables adhered to the decreasing returns law [23], with an initial increasing segment and a subsequent decreasing one. Both constructs exhibited a strong positive influence on the results (FES) at very low (negative) levels of FS and BF. This impact is moderated for positive values of both agro-system variables. The results showed an upward trend, suggesting that improving practices in the Amazonian Chakra entails a significant improvement in results. A significant relationship was found between sustainability constructs and economic performance, characterized by a sigmoid shape curve like the Cobb-Douglas function with decreasing returns concerning productive factors [23,79,80].

Surprisingly, the results related to Hypothesis 4 were rejected. No significant relationship was found between SF and the results (FES), and, furthermore, the parameter sign is opposite to what was expected ($\beta = -0.07$).

4. Discussion

A quantitative relationship was established between the sustainability indicators of the SAFA system and the economic and financial outcomes through a PLS-SEM, representing a valuable tool to quantify the relationships between sustainability indices (ER, BC, FS, and SF) and the final results in the agroforestry systems, the Amazonian Chakra [62,81–83]. These findings are supported by existing literature, indicating that small-scale farmers in various regions, such as the Mediterranean basin, the tropical Americas (Mexico and Ecuador) [84], and South Africa, face similar strategic challenges in their pursuit of food security, family well-being, and poverty reduction [63,82,83,85].

Regarding the main objective of this research, it is concluded that sustainability indices related to environmental resilience (Hypothesis 1) and business factors (Hypothesis 5) showed a strong negative and positive influence, respectively, on the FES of the Amazonian Chakra. Additionally, BC and FS indicators had a significant effect (99%) on FES. Hypotheses 2 and 3 were validated, although these constructs showed a weak effect.

Hypotheses 3 and 5 were positively confirmed, indicating that practices related to FS and BF have a significantly positive impact on FES in agroforestry production systems. This finding is in line with current literature, emphasizing the importance of these sustainability dimensions for enhancing economic and financial outcomes in agroforestry contexts [63,83,85,86].

The positive influence of food security suggests that strategies ensuring the availability and quality of food to meet dietary needs and food preferences, as well as promoting an active and healthy lifestyle, can significantly contribute to strengthening FES [85,87].

Similarly, business factors, by promoting responsible and ethical business practices, can generate economic benefits for agroforestry production systems [71].

In contrast, the ER and BC indicators, corresponding to Hypotheses 1 and 2 respectively, had a negative impact on the Chakra's FES, as did SF. These findings align with the existing literature that emphasizes the interplay between economic activities and environmental quality [88–91]. These authors underscore that excessive dependence or undue pressure on the environment from these activities can have adverse consequences and harm its quality. However, BC can positively impact long-term economic sustainability in various ways [92].

Our findings reflect common tensions between economic activities and environmental health. Although these results may be surprising, they are consistent with the idea that environmental resilience does not always lead to immediate economic benefits, especially in regions where traditional environmental conservation practices may require significant short-term investments.

These results are essential for understanding the sustainability dynamics in specific agroforestry environments. The negative influence of ER and BC suggests that, in the Chakra Amazónica, a greater focus on these practices may not necessarily lead to improvements in FES. This finding underscores the need to carefully consider sustainability strategies based on the local context and environmental conditions.

Hypothesis 4, related to social factors, was not verified with a 99% level of confidence. This may be due to the diversity of social factors that can influence economic-financial sustainability, requiring a more detailed evaluation. The diversity of social factors, ranging from social capital to cultural and demographic diversity, can have significant implications for the ability of systems to remain economically sustainable [93,94].

Policy Implications for Sustainability

In the context of promoting food security and sustainable agriculture, food security has a positive impact on the financial sustainability of cocoa producers in the Chakra. Therefore, it is suggested that public policies focus on strengthening local food production and availability. This approach should include the promotion of sustainable agricultural practices and support for crop diversification, which would contribute to ensuring the food security and sovereignty of local communities [95,96].

Promoting the development of business management could incentivize companies to adopt socially responsible practices, such as fair trade and investment in local communities. To achieve this goal, more effective tax incentives or regulations could be implemented [97] that recognize and reward cooperative businesses, demonstrating a significant commitment to business factors geared toward promoting good practices within the Amazonian Chakra system and, consequently, their involvement in special markets [97].

Since environmental resilience and biodiversity conservation can have negative effects on financial sustainability in certain contexts, it is essential to strike a balance between environmental conservation and local communities' economic well-being. This could involve reviewing environmental regulations and promoting sustainable agricultural practices in deforestation-free areas that positively encourage increased income through access to markets that recognize the quality not only of the products but also the production system.

In this regard, the importance of promoting a comprehensive management approach that addresses not only economic and financial dimensions, but also social and environmental aspects, is emphasized. This could be achieved through support for incentive-based market solutions for those who choose to engage in sustainable agricultural strategies [98,99], as well as through training programs that promote the sustainable management of natural resources and the adoption of agricultural practices that consider multiple aspects of sustainability.

5. Conclusions

Food security and business factors have a positive and significant impact on the financial and economic sustainability of cocoa producers using the Amazonian Chakra system. This underscores the importance of ensuring the availability and quality of food, as well as promoting ethical and socially responsible business practices to improve economic outcomes in this system.

The negative impact of the environmental resilience and biodiversity conversion factors on FES suggests that, in the context of the Chakra, an excessive focus on these areas may not be as effective in driving the FES of cocoa producers, risking the abandonment of this important system.

No significant evidence was found for social factors in relation to FES. This indicates that, at least in this study, social aspects do not have a clear and measurable impact on the economic outcomes of cocoa producers in the Chakra.

This study provides valuable practical guidance for farmers, agricultural organizations, and policymakers interested in improving economic sustainability in cocoa production in the Chakra. By highlighting the potential negative impacts of an excessive focus on environmental resilience and biodiversity conversion, the research offers useful warnings and guidance for balancing conservation and production goals in agroforestry systems, enriching both theoretical knowledge and practical tools available.

Furthermore, the study has demonstrated the utility of the partial least squares structural equation model (PLS-SEM) as a valuable tool for quantifying the relationships between sustainability indicators and economic-financial outcomes in traditional agroforestry systems. Overall, the results emphasize the importance of holistic management that addresses both economic-financial and social-environmental dimensions in the Chakra system.

For future research, conducting longitudinal and comparative studies is suggested to better understand the temporal and regional dynamics of economic sustainability. It is also important to explore previously unconsidered variables, develop more integrated models, and evaluate the impact of specific policies and practices. Detailed case studies and research on the influence of community participation can enhance our understanding of economic sustainability in agroforestry systems such as the Amazonian Chakra. These research directions would expand knowledge and help promote farmers' economic sustainability.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to they belong to a research project that is still working on other contributions.

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Appendix A Description of Constructs and Indicators in the Structural Model

Table A1. Constructs and Indicators.

Constructs and Indicators	Mean Values
	n = 330
Environmental Resilience (ER)	
Greenhouse gas emission reduction objective	3.48
Water conservation practices	3.26
Water pollution prevention practices	4.14
Ecosystem improvement practices	3.91
Land Use and Land Cover Change (LULCC)	3.78
Seed and breed savings	3.83
Land conservation and rehabilitation	3.86
Material consumption practices	3.78
Renewable and recycled materials	3.08
Energy-saving practices	2.39
Waste reduction practices	3.50
Food loss and waste reduction practices	3.69

Table A1. *Cont.*

Constructs and Indicators	**Mean Values**
	n = 330
Biodiversity Conservation (BC)	
Ecosystem connectivity	3.96
Species diversity/abundance	3.94
Productive diversity	4.00
Agrobiodiversity conservation	4.07
Soil chemical quality	3.93
Soil biological quality	3.98
Soil organic matter	3.85
Land gain/loss of productive land	3.86
Food Security (FS)	
Guarantee of production levels	3.35
Diversification of products	3.59
Safety nets	2.96
Risk management	3.31
Control measures	3.96
Dangerous pesticides	4.20
Food contamination	4.18
Food quality	3.96
Traceability	3.81
Certified production	3.67
Social Factors (SF)	
Right to quality of life	4.14
Capacity development	3.52
Fair prices and transparent contracts	3.30
Non-discrimination	4.30
Gender equality	4.33
Support for vulnerable people	4.08
Health and safety training	3.47
Public health	4.19
Indigenous knowledge	4.26
Food sovereignty	4.34
Business Factor (BF)	
Mission Statement	3.08
Driven mission	3.07
Holistic audits	3.11
Transparency	3.05
Stakeholder engagement	3.25
Effective participation	3.05
Complaint procedures	3.11
Conflict resolution	3.25
Free, Prior, and Informed Consent (FPIC)	3.49
Tenure rights	3.46
Total cost accounting	3.18
Market stability	3.09
Business plan	3.15
Financial-Economic Sustainability (FES)	
Domestic investment	3.29
Community investment	3.47
Long-term profitability	3.23
Cash flow	3.09
Net income	3.19
Production costs	3.15
Price determination	3.26

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