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AGRICULTURAL PRACTICES AND ENVIRONMENTAL SUSTAINABILITY: THE ROLE OF PERCEIVED BENEFITS IN LOCAL PRODUCTION SYSTEMS. EVIDENCE FROM THE CANTON PATATE USING STRUCTURAL EQUATION MODELING (SEM)

Tania Morales-Molina[1*], Mery Ruiz-Guajala[2], Cesar Mayorga-Abril[3], Paúl Condo-Allaica[4], and Franck Palacios-Ruiz[5]

[1]Universidad Tecnológica Indoamérica, Ecuador. taniamorales@uti.edu.ec,
https://orcid.org/0000-0002-9267-0946
[2]Universidad Técnica de Ambato, Ecuador. meryeruiz@uta.edu.ec, https://orcid.org/0000-0002-3684-7778
[3]Universidad Técnica de Ambato, Ecuador, Ecuador. cesarmmayorga@uta.edu.ec,
https://orcid.org/0000-0001-8671-4757
[4]Universidad Técnica de Ambato, Ecuador, Ecuador. pcondo1241@uta.edu.ec,
https://orcid.org/0000-0001-6311-6658
[5]Universidad Técnica de Ambato, Ecuador, Ecuador. fp.palacios@uta.edu.ec,
https://orcid.org/0009-0004-6333-4806

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Corresponding Author: Tania Morales-Molina
(taniamorales@uti.edu.ec)

ABSTRACT

Agricultural sustainability represents a central challenge for small-scale production systems, particularly in rural territories where pressure for immediate profitability conditions the adoption of environmentally responsible practices. In this context, this article analyzes the influence of perceived economic benefits on the environmental sustainability of farmers in the canton of Patate, Ecuador, using an empirical approach based on Structural Equation Modeling (SEM). The study is grounded in the triple sustainability framework and in the literature that highlights the role of economic incentives as a key driver of change in agricultural systems. Accordingly, a quantitative research design with a correlational–causal scope was employed, using primary data collected through surveys administered to agricultural producers. Model fit was assessed using absolute, incremental, and parsimony indices, which demonstrated adequate consistency and validity of the proposed model. The structural results showed that agricultural practices exerted a positive and significant direct effect; however, the effect of perceived benefits on environmental sustainability was considerably stronger, confirming their role as a key mediating mechanism in the adoption and persistence of sustainable practices. These findings indicate that environmental sustainability in Patate is strongly conditioned by perceptions of profitability, which helps explain the coexistence of conventional and conservation-oriented practices within hybrid production systems. Accordingly, this study provides empirical evidence reinforcing the need for public policy and agricultural extension strategies aimed at demonstrating the economic benefits of sustainable

practices as a necessary condition for strengthening environmental resilience and long-term agricultural production in similar rural contexts.

KEYWORDS: Sustainability, economic, social, environmental, agricultural practices, perceived benefits, Structural Equation Modeling (SEM).

1. INTRODUCTION

Currently, agriculture faces a systemic challenge of global scope: ensuring food security for a population projected to exceed 10 billion people by 2050, which implies an estimated 70% increase in food production (Kumar et al., 2024). However, this productive imperative unfolds in a context of increasing degradation of natural resources, particularly soil, a key element for agricultural productivity, agroecosystem stability, and carbon sequestration. It is estimated that nearly half of the world's arable land exhibits some degree of degradation, mainly attributable to intensive and inappropriate agricultural practices, such as conventional tillage, which exposes soil to solar radiation and oxygen, accelerating the loss of organic matter and increasing susceptibility to erosion (Feng et al., 2025).

From an environmental perspective, the agricultural sector constitutes one of the primary drivers of pressure on natural systems. At the global level, agriculture accounts for approximately 90% of freshwater consumption and represents a significant share of anthropogenic nitrogen and phosphorus flows within the Earth's biogeochemical cycles (Zhang et al., 2021). Moreover, the increasing dependence on synthetic pesticides has given rise to the so-called pesticide treadmill, a phenomenon in which increases in gross domestic product (GDP) are associated with higher use of chemical inputs, thereby intensifying environmental contamination and risks to human health. This situation is particularly critical in agrarian economies, where production intensification tends to prioritize immediate yields, often at the expense of environmental externalities and the ecological resilience of productive systems (Wyckhuys et al., 2022).

Against this backdrop, the scientific literature has emphasized the need to transition toward models of sustainable intensification, based on practices such as crop rotation, the use of organic fertilizers, vegetative cover, and minimum tillage. These strategies have been shown to significantly reduce water stress, erosion, and soil degradation across a large share of crops exposed to extreme climatic events (Feng et al., 2025; Sardo et al., 2024). Likewise, the emergence of Agriculture 4.0, which integrates technologies such as the Internet of Things (IoT) and artificial intelligence, offers opportunities to optimize input use, improve productive efficiency, and reduce environmental impacts; however, its adoption remains uneven, particularly in small-scale farming systems (Kumar et al., 2024; Mana et al., 2024).

Another relevant axis of agricultural sustainability is the management of organic waste under circular economy approaches. In various contexts, both European and Latin American, the valorization of agricultural by-products—such as straw, pruning residues, or fruit peels—has enabled the development of bioproducts that reduce the sector's environmental burden. However, the implementation of these solutions is often constrained by the high initial energy demand of transformation processes, highlighting the need to integrate renewable energy sources to ensure the environmental coherence of the transition (Amato et al., 2021; Mana et al., 2024).

Beyond technological and technical advances, the effective adoption of sustainable agricultural practices constitutes a fundamentally economic and cognitive challenge. From the perspective of the producer's rational behavior theory, farmers are conceived as optimizing agents who prioritize financial viability and the stability of their livelihoods before committing to long-term environmental objectives (Valcourt et al., 2024; Wyckhuys et al., 2022). In this context, perceived benefits (PB)—such as cost reduction, production stability, and improved soil fertility—emerge as a decisive factor conditioning the environmental sustainability (ES) of agricultural systems, particularly in family farming and small-scale agricultural contexts (Touch et al., 2024; Valcourt et al., 2024).

Empirical evidence suggests the existence of an implementation gap between available agroecological knowledge and its effective application in the field. While scientific research on agricultural sustainability continues to expand, the adoption of sustainable practices tends to stagnate when producers fail to identify clear economic incentives or perceive high levels of financial risk. Structural factors such as market access, land tenure security, and the availability of technical assistance play a decisive role in production decision-making, frequently tipping the balance toward conventional strategies oriented to short-term income (Seipel et al., 2019; Wyckhuys et al., 2022).

Despite the proliferation of global conceptual frameworks, such as the Triple Bottom Line approach, a significant gap in quantitative evidence persists in rural contexts of Latin America, particularly in Andean regions characterized by high climatic variability and small-scale production systems. In Ecuador, extreme events such as the 2017 Coastal El Niño highlighted the high vulnerability of rural infrastructure and producers to floods and landslides, further exacerbating existing sustainability gaps (Rollenbeck et al., 2022).

In this context, studies employing advanced multivariate methods to analyze the structural relationships between economic perceptions, agricultural practices, and environmental outcomes at the farm level remain limited. Most existing research relies on descriptive analyses or aggregated climatic information, which hinders the ability to capture the microclimatic and socioeconomic dynamics specific to highly productive agricultural territories, such as the canton of Patate in the Andean region of Ecuador.

In response to this gap, the objective of the present study is to determine the influence of perceived economic and technical benefits on the environmental sustainability of farmers in Patate, Ecuador, assessing whether the economic dimension acts as the articulating axis that supports the social and environmental dimensions, in line with the Triple Bottom Line approach. To this end, a Structural Equation Modeling (SEM) framework is employed, a multivariate statistical technique that allows the simultaneous testing of causal relationships between observable variables and latent constructs, while incorporating measurement errors as well as direct and indirect effects (Manzano Patiño, 2017; Ruiz et al., 2010). This approach is particularly suitable for analyzing how the subjective perception of benefits conditions the adoption of agricultural practices and, ultimately, the achievement of environmental sustainability, providing a robust empirical basis for the design of agricultural extension policies tailored to the realities of Ecuadorian producers (Lepera, 2021).

Consistent with the theoretical framework and the rational producer behavior theory, this study is based on the assumption that environmental sustainability in small-scale agricultural systems does not depend solely on the isolated adoption of agricultural practices, but rather on producers' perceptions of the economic and technical benefits associated with such practices. Accordingly, the study hypothesizes that higher perceived benefits (PB) exert a positive and significant effect on both the adoption of sustainable agricultural practices (AP) and the level of environmental sustainability (ES). Moreover, it is posited that agricultural practices act as a partial mediating mechanism in the relationship between perceived benefits and environmental sustainability, thereby configuring a causal framework consistent with the proposed structural equation modeling approach.

2. METHODOLOGY

The present study adopts a quantitative approach with an explanatory scope and is conducted under a non-experimental, cross-sectional research design. Accordingly, data collection was carried out at a single point in time, allowing for the analysis of interrelationships among variables without deliberate manipulation, which is appropriate for the study of socio-environmental phenomena in real agricultural contexts.

The dataset comprises 2,900 observations collected from rural farmers in the canton of Patate, Ecuador. Accordingly, the inclusion criteria required participants to be landowners or directly responsible for agricultural holdings, with a minimum of two years of experience in local productive activities. Data collection was conducted using a structured questionnaire validated through expert judgment, which enabled the operationalization of the study's core variables: Agricultural Practices (AP), Perceived Benefits (PB), and Environmental Sustainability (ES). The items were predominantly measured using a five-point Likert-type scale, suitable for capturing perceptions, attitudes, and behaviors in social and productive contexts. Surveys were administered in person to farmers affiliated with agricultural associations in the canton.

Statistical analyses were conducted using IBM SPSS Statistics for descriptive analysis and reliability assessment, and JASP for the estimation of the structural equation model and the testing of the proposed hypotheses.

The analysis is grounded in a mediated correlational–causal approach, using Structural Equation Modeling (SEM) as the primary analytical technique. SEM is particularly suitable for testing theoretical models that posit direct and indirect relationships between latent and observed variables, allowing the evaluation of complex causal structures on an empirical basis (Ruiz et al., 2010). This approach is especially appropriate for studies in social sciences applied to agriculture, where constructs such as agricultural practices, perceived benefits, and environmental sustainability are not directly observable and must be operationalized through multiple indicators (Doral Fábregas et al., 2018; Hair et al., 2019). Accordingly, the model provides the foundation for the empirical analysis by simultaneously integrating a measurement model and a structural model, thereby enabling the assessment of causal relationships among latent variables that are not directly observable (Bollen, 1989; Kline, 2016).

In the structural model, consistent with the theoretical framework and the objectives of the study, a mediated causal model is proposed in which Agricultural Practices (AP) exert both direct and indirect effects—through Perceived Benefits (PB)—on Environmental Sustainability (ES). Formally, the structural model is expressed through the following system of equations:

BP=γ1PA+ζ1

SA=β1BP+γ2PA+ζ2

where:

AP represents the exogenous latent variable Agricultural Practices.

PB corresponds to the mediating latent variable Perceived Benefits.

ES is the endogenous latent variable Environmental Sustainability.

γ_1 y γ_2 are the structural coefficients that capture the direct effects of AP on PB and ES, respectively.

β_1 represents the direct effect of PB on ES.

ζ_1 y ζ_2 are the structural error terms, which capture the variance not explained by the model.

This specification allows for the estimation of the total effect of agricultural practices on environmental sustainability by decomposing it into a direct effect (γ2) and an indirect effect mediated by perceived benefits (γ1×β1), Moreover, for the measurement model, each latent variable was operationalized through a set of observable indicators collected via the structured questionnaire. The measurement model is expressed as follows:

For Agricultural Practices (AP):

X_(PA_i)=λ_(PA_i) "PA"+ε_(PA_i)

For Perceived Benefits (PB):

X_(BP_j)=λ_(BP_j) "BP"+ε_(BP_j)

For Environmental Sustainability (ES):

X_(SA_k)=λ_(SA_k) "SA"+ε_(SA_k)

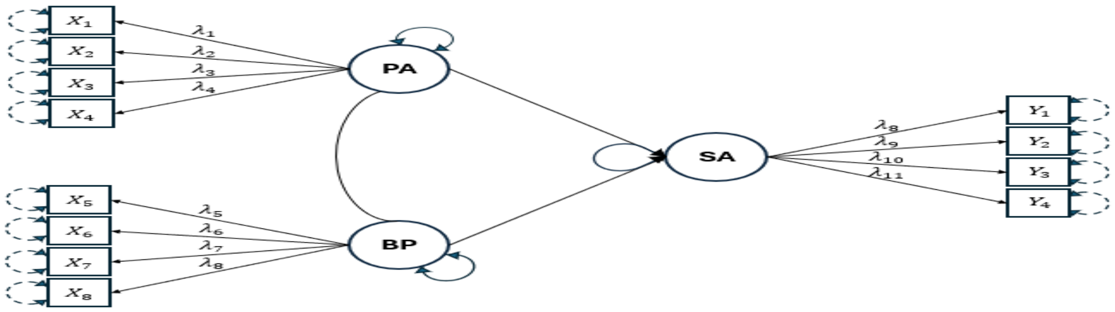
Where:

X_(PA_i), X_(BP_j) y X_(SA_k) represent the observed indicators of each construct.

λ are the factor loadings, which reflect the extent to which each item explains its respective latent variable.

ε corresponds to the measurement error associated with each indicator.

The mathematical specification of the SEM model allows for the empirical evaluation of the central hypothesis of the study, according to which perceived benefits act as a key mediating mechanism in the relationship between agricultural practices and environmental sustainability (Chou et al., 2015). This approach is consistent with the literature, which argues that the adoption and persistence of sustainable practices depend largely on producers' perceptions of profitability and utility, particularly in family farming and small-scale agricultural contexts.



The proposed Structural Equation Model (SEM) shown in Figure 1 provides an integrated representation of the causal and mediating relationships among agricultural practices (AP), perceived benefits (PB), and environmental sustainability (ES) among farmers in the canton of Patate. In this framework, agricultural practices constitute an exogenous latent variable, operationalized through observable indicators related to soil management, input use, conservation techniques, and productive practices. Perceived benefits act as a mediating latent variable, reflecting producers' subjective evaluation of the economic, productive, and operational returns derived from the adoption of specific agricultural practices. In turn, environmental sustainability is modeled as an endogenous latent variable, measured through indicators associated with soil conservation, reduction of environmental impacts, efficient use of natural resources, and the resilience of the production system.

The model explicitly distinguishes between the measurement model, which links latent variables to their respective observed indicators, and the structural model, which captures the direct and indirect effects among AP, PB, and ES. This distinction allows for the assessment of both the direct influence of agricultural practices on environmental sustainability and the mediating role of perceived benefits. This approach is methodologically appropriate for analyzing complex agricultural systems, where production decisions are shaped by both technical and perceptual factors, and it is grounded in the capacity of SEM to simultaneously test causal relationships between latent and observed variables (Lepera, 2021; Ruiz et al., 2010).

To validate the SEM framework, model fit indices were considered and required to exceed theoretically established thresholds in order to demonstrate that the model provides relevant and statistically meaningful information. Accordingly, Table I presents the fit indices and their corresponding values used for model adjustment and validation.

Table 1: SEM Model Fit Indices.

Statistic	Ratio	Detail
x^2, df, p	$p > \propto =$,05. Good fit	Model Chi-square statistic
$\frac{x^2}{df}$	≤ 2 o 3 Acceptable fit	Normed chi-square statistic (χ^2/df).
RMSEA	≤ ,06 Acceptable ≤ ,05 Excellent	Steiger–Lind Root Mean Square Error of Approximation (RMSEA).
CFI	≥ ,90 Acceptable ≥ ,95 Excellent	Bentler's Comparative Fit Index (CFI).
SRMR	≤ ,10 Acceptable ≤ ,08 Excellent	Standardized Root Mean Square Residual (SRMR).
TLI (NNFI)	≥ ,90 Acceptable ≥ ,95 Excellent	Tucker–Lewis Index (Non-Normed Fit Index, TLI).
GFI	≥ ,90 Acceptable ≥ ,95 Excellent	Jöreskog–Sörbom Goodness-of-Fit Index (GFI).
PNFI	≥ ,50 Acceptable	Parsimonious Normed Fit Index (PNFI).
PRATIO	≥ ,50 Acceptable	Parsimony ratio.

These indices must meet theoretically established thresholds in order to ensure that the model provides statistically meaningful and conceptually consistent information. In this regard, Table 1 presents the main fit indices, their acceptance criteria, and their methodological interpretation. These include the chi-square statistic and its normalized ratio (χ^2/df), which assess the overall discrepancy between the model and the observed data; the RMSEA, which measures the model's approximation error; and the incremental fit indices CFI and TLI, which compare the fit of the proposed model against a null model. In addition, the SRMR is included as an indicator of the standardized mean residual. Furthermore, parsimony indices such as the PNFI and the parsimony ratio (PRATIO) are incorporated to evaluate the balance between model complexity and explanatory power. The joint consideration of these indices enables a comprehensive assessment of the model's overall fit, ensuring the statistical robustness and scientific validity of the conclusions regarding the influence of perceived benefits on the environmental sustainability of farmers in Patate.

3. RESULTS

This section presents the results derived from the descriptive analysis of the variables considered in the study. This analysis allows for the identification of general patterns, frequencies, trends, and predominant behaviors within the studied population, constituting an essential empirical basis for the subsequent interpretation of the relationships among the variables included in the model. Likewise, the descriptive results facilitate an initial understanding of the local productive context and the socioeconomic and technical conditions under which agricultural activities are carried out, providing an interpretative framework for the subsequent structural analysis.

Table I. Frequencies of the Adoption of Agricultural Practices.

		Frequency	**Percent**	**Valid percent**	**Cumulative percentage**
Crop rotation	No	71	71,0	71,0	71,0
	Si	29	29,0	29,0	100,0
	Total	100	100,0	100,0	
Organic fertilizers	NO	5	5,0	5,0	5,0
	SI	95	95,0	95,0	100,0
	Total	100	100,0	100,0	
Synthetic fertilizers	NO	8	8,0	8,0	8,0
	SI	92	92,0	92,0	100,0
	Total	100	100,0	100,0	
Reduced tillage	NO	77	77,0	77,0	77,0
	SI	23	23,0	23,0	100,0
	Total	100	100,0	100,0	
Direct seeding	NO	84	84,0	84,0	84,0
	SI	16	16,0	16,0	100,0
	Total	100	100,0	100,0	

Table 1 reveals a markedly uneven adoption of agricultural practices in the canton of Patate. While 92% of producers use chemical fertilizers, only 16% apply direct seeding and merely 23% employ minimum tillage. Although the use of organic fertilizers reaches a high 95%, this practice does not replace but rather coexists with a strong dependence on external inputs. This pattern indicates the presence of hybrid production systems in which sustainable practices are incorporated only partially, without a comprehensive transition toward conservation-oriented management models. In a territory where agriculture—particularly fruit production and certain tubers—constitutes the main economic activity, this combination of practices reflects a fragile and unstable form of sustainability, conditioned by the priority given to immediate productivity over long-term resource conservation.

Structural Equation Modeling (SEM) is a confirmatory multivariate statistical technique that allows complex theoretical models to be tested against the empirical reality observed in a given sample (Manzano Patiño, 2017). In this study, the overall fit of the environmental model for farmers in the canton of Patate was evaluated using several goodness-of-fit statistics, which determine whether the proposed causal structure is consistent with the empirical data collected.

Table II. Model Fit.

				n(Parameters)		Baseline test		
	AIC	BIC	n(Observations)	Total	Free	χ^2	df	p
Model 1			100	65	65	92.08	74.00	.076

Table 2 confirms the validity of the model, as the p-value of 0.076 indicates a good model fit by exceeding the 0.05 threshold. This result suggests that there is no significant discrepancy between the covariance matrix observed in the sample and the matrix reproduced by the model, thereby allowing the null hypothesis—that the theoretical model is adequate—to be retained. Furthermore, the normalized chi-square value of 1.244 supports the continuation of the structural equation modeling analysis for the environmental dimension.

Table 3: Model Fit Indices.

Index	Value
Comparative Fit Index (CFI)	0.970
Tucker-Lewis Index (TLI)	0.964
Bentler-Bonett Non-normed Fit Index (NNFI)	0.964
Bentler-Bonett Normed Fit Index (NFI)	0.869
Parsimony Normed Fit Index (PNFI)	
Bollen's Relative Fit Index (RFI)	0.839
Bollen's Incremental Fit Index (IFI)	0.971
Relative Noncentrality Index (RNI)	0.970
Root mean square error of approximation (RMSEA)	0.050
RMSEA 90% CI lower bound	0.000
RMSEA 90% CI upper bound	0.080
RMSEA p-value	0.485
Standardized root mean square residual (SRMR)	0.114
Hoelter's critical N (α = .05)	122.450
Hoelter's critical N (α = .01)	135.377
Goodness of fit index (GFI)	0.971
McDonald fit index (MFI)	0.982
Expected cross validation index (ECVI)	

Regarding the incremental fit indices, the CFI (0.970) and TLI (0.964) clearly exceed the recommended threshold of 0.95, demonstrating a substantial improvement of the proposed model relative to the null independence model. Likewise, the Root Mean Square Error of Approximation (RMSEA = 0.050) lies at the threshold of excellent fit, indicating a minimal approximation error relative to the degrees of freedom. Although the SRMR (0.114) is slightly above the optimal benchmark of 0.08, the high values of the GFI (0.971) and MFI (0.982) confirm that the proportion of variance and covariance explained by the model is remarkably high, collectively validating the integrity and robustness of the proposed theoretical structure.

Table 4: Structural Relationships Among Variables.

					95% Confidence interval	
	Estimate	Std. Error	z-value	p	Lower	Upper
PA → SA	0.290	0.118	2.455	.014	0.059	0.521
BP → SA	0.720	0.087	8.319	< .001	0.550	0.889

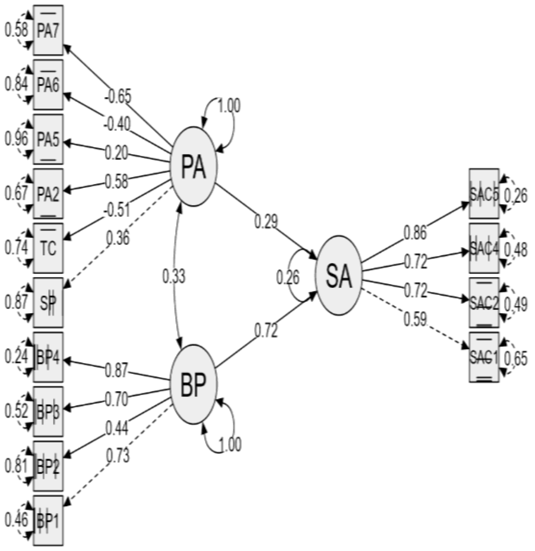


Figure 1. Structural path diagram for the environmental dimension.

The analysis of the model paths reveals the differential importance of the factors driving environmental sustainability in the rural context of Patate. The relationship between Agricultural Practices (AP) and Environmental Sustainability (ES) showed a positive and statistically significant standardized coefficient (β = 0.290, p = 0.014). This finding confirms that the technical implementation of methods such as direct seeding, crop rotation, and the use of organic fertilizers constitutes an indispensable material means for the conservation of productive resources. However, the magnitude of the coefficient indicates that the direct impact of technical practices on environmental sustainability is moderate when compared to perceptual factors.

By contrast, the relationship between Perceived Benefits (PB) and Environmental Sustainability (ES) emerged as the dominant and highly significant factor in the model (β = 0.720, p < 0.001). The magnitude of this relationship is more than twice that of technical practices, establishing that perceptions of economic viability, cost reduction, and improved soil quality act as the primary catalyst for achieving environmental goals. This result is critical for sustainable planning, as it suggests that the adoption of environmentally responsible practices in Patate is driven predominantly by expectations of economic stability and profitability.

5. DISCUSSION

The results of this study confirm that the environmental sustainability of farmers in the canton of Patate does not depend exclusively on the technical implementation of sustainable agricultural practices, but is instead strongly conditioned by perceptions of the economic and productive benefits associated with such practices. The Structural Equation Modeling (SEM) results reveal a relational structure in which agricultural practices exert a positive influence on environmental sustainability; however, this effect is considerably smaller than the impact driven by perceived benefits. This pattern is consistent with recent literature highlighting the central role of subjectively perceived economic incentives in shaping sustainable agricultural decision-making in small-scale contexts (Getahun et al., 2024; Nguyen et al., 2024; Sardo et al., 2024).

The direct effect of agricultural practices on environmental sustainability (β = 0.290; p = 0.014) confirms that the adoption of conservation-oriented techniques—such as soil management, the incorporation of organic fertilizers, and the partial reduction in agrochemical use—generates measurable environmental improvements. Nevertheless, the moderate magnitude of this effect suggests that a fragmented adoption of sustainable practices is insufficient to consolidate a stable environmental transition. Similar findings have been reported by Viana et al. (2021) and Hinz et al. (2020), who show that the coexistence of conventional and sustainable practices leads to partial improvements, particularly when economic, institutional, and technological constraints persist.

By contrast, the effect of perceived benefits on environmental sustainability is substantially stronger (β = 0.720; p < 0.001), indicating that perceptions of profitability, risk reduction, and productive stability act as the primary catalysts of sustainable agricultural behavior. This finding provides empirical support for previous studies showing that farmers prioritize practices that maximize expected benefits, even above environmental or regulatory motivations (Autio et al., 2021; Candemir et al., 2021; Higgins et al., 2017; Razanakoto et al., 2021). In this sense, environmental sustainability emerges as an indirect outcome of rational economic decision-making rather than as an autonomous conservation objective.

However, the realization of these perceived benefits is frequently constrained by institutional and governance barriers that condition the effective adoption of sustainable technologies. Even in contexts where reforms in water property rights or other resources have been implemented, the absence of extension services, technical support, and adequate economic incentives generates reluctance among farmers to modify their production systems

(Chen et al., 2024). This interaction between economic rationality and structural constraints helps explain why the adoption of sustainable practices remains partial or fragmented across many rural contexts.

From a theoretical perspective, this behavior aligns with Producer Theory, which posits that farmers act as rational agents seeking to optimize their utility under conditions of uncertainty, prioritizing income stability and the reduction of production risks (Valcourt et al., 2024; Varian, 2019). In Patate, farmers tend to adopt sustainable practices to the extent that these generate tangible benefits, such as reduced input costs, improved soil fertility, or greater yield stability. This behavior confirms that the environmental dimension is functionally subordinated to the economic dimension, as has been documented in rural contexts across Latin America, Africa, and Asia (Malapane et al., 2024; Touch et al., 2024).

These results also support the Triple Bottom Line approach, according to which sustainability is only viable when there is an operational balance among the economic, social, and environmental dimensions. Recent studies show that the economic dimension acts as a prerequisite for the adoption of environmentally responsible practices, particularly in family farming systems (Peñuelas et al., 2023; Zhang et al., 2021). In the present study, perceived benefits function as the articulating axis that enables environmental sustainability, thereby providing empirical reinforcement for this conceptual framework.

The evidence found in Patate is consistent with studies describing the persistence of the so-called "chemical input trap," in which farmers continue to rely on fertilizers and pesticides to secure immediate yields, even while recognizing their negative environmental impacts (Król-Badziak et al., 2021; Wyckhuys et al., 2022). The high use of chemical fertilizers (92%), combined with a high adoption of organic fertilizers (95%), reflects the existence of hybrid systems oriented toward mitigating production risks rather than maximizing long-term environmental benefits.

In comparison with highly technologized agricultural systems in Europe, where technological innovation enables the reduction of environmental impacts without compromising productivity, Latin American farmers face structural barriers that limit a full transition toward sustainability (Caicedo-Vargas et al., 2022; Pérgola et al., 2024). In Patate, sustainability is configured as a subsistence strategy rather than as an explicit pursuit of environmental neutrality, which explains the selective adoption of low-cost sustainable practices.

Likewise, demographic factors such as the aging of the rural population and youth migration constrain the adoption of labor-intensive practices, such as minimum tillage—a phenomenon widely documented in studies of producers in developing economies (Devkota et al., 2020; Valcourt et al., 2024). These constraints reinforce the preference for chemical inputs as mechanisms of productive simplification. Another relevant contribution of this study is the indirect evidence of the mediating role of perceived benefits between agricultural practices and environmental sustainability. Although the model did not include an explicit mediation test, the substantial difference between the estimated coefficients suggests that agricultural practices generate more robust environmental impacts when farmers identify clear economic benefits, a result consistent with studies based on SEM applied to agricultural sustainability (Autio et al., 2021; Ruiz et al., 2010).

Finally, this study contributes to the Latin American literature on agricultural sustainability, a field that remains largely dominated by research conducted in Asia and Africa (Viana et al., 2021). The application of an SEM approach in Patate provides localized and policy-relevant evidence for the design of public policies aimed at promoting sustainable practices through explicit economic incentives. Despite the methodological limitations associated with the cross-sectional design and the use of self-reported data, the consistency of the findings with the international literature reinforces their validity and scientific relevance.

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