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ANALYSIS OF SUSTAINABLE TECHNOLOGIES IN AGRICULTURE THROUGH STRUCTURAL ASSESSMENTS

Ángel Wilkins Álvarez Pincay[1]*, Ghenkis Amílcar Ezcurra Zavaleta[2], Edwin Alberto Ubillus Agurto[3], Aldrin Jefferson Calle García[4], Yixcely Maribel Espinoza Tuárez[5], Mónica del Pilar Quiñónez Cercado[6]

[1]Economista, Magíster en Administración Pública, Mención: Evaluación de Proyectos https://orcid.org/0000-0002-8677-2372 Universidad Nacional de Tumbes: aalvarezp@epguntumbes.edu.pe Universidad Estatal del Sur de Manabí: angel.alvarez@unesum.edu Ecuador-Jipijapa
[2]Licenciado en Administración. Doctor en Planificación Pública y Privada Universidad Nacional de Tumbes: gezcurraz@untumbes.edu.pe Perú-Tumbes
[3]Economista. Doctor en Administración https://orcid.org/0000-0003-2917-9959 Universidad Nacional de Tumbes: eubillusa@untumbes.edu.pe Perú-Tumbes
[4]Economista. Doctor en Administración https://orcid.org/0000-0003-0178-4428 Universidad Nacional de Tumbes: a.calle.garcia@posgradountumbes.edu.pe Universidad Estatal del Sur de Manabí: aldrin.calle@unesum.edu.ec Ecuador-Jipijapa
[5]Licenciada en Ciencias de la Educación. Magíster en Gerencia Educativa https://orcid.org/0009-0007-7735-1772 Universidad Nacional de Tumbes: mespinuc@epguntumbes.edu.pe Universidad Estatal del Sur de Manabí: yixcely.espinoza@unesum.edu.ec Ecuador-Jipijapa
[6]Ingeniera en Auditoría. Magíster en Contabilidad y Auditoría https://orcid.org/0009-0005-6559-4617 Universidad Nacional de Tumbes: m.quinonez.cercado@posgradountumbes.edu.pe Universidad Estatal del Sur de Manabí: monica.quinonez@unesum.edu.ec Ecuador-Jipijapa

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Corresponding Author: Ángel Wilkins Álvarez Pincay (aalvarezp@epguntumbes.edu.pe)

SUMMARY

This study analyzes the influence of rural associations on the adoption of sustainable technologies in Ecuadorian agriculture using structural economic models (SEMs), which integrate organizational, institutional, and sociocultural factors. The results, based on a simulated sample of 300 producers, demonstrate a robust model (CFI = 0.94, TLI = 0.93, RMSEA = 0.048, SRMR = 0.041). Rural associations significantly impact institutional support ($\beta = 0.61$, $p < 0.001$) and social capital ($\beta = 0.54$, $p < 0.001$), strengthening cohesion and access to resources. Institutional support ($\beta = 0.45$, $p < 0.001$) and social capital ($\beta = 0.39$, $p < 0.001$) influence the perception of usefulness, which in turn affects capacity/access ($\beta = 0.42$, $p < 0.001$) and technology adoption ($\beta = 0.29$, $p = 0.002$). Capacity/access is a key factor in adoption ($\beta = 0.37$, $p < 0.001$). Indicators such as formalization (0.81), technical assistance (0.84), trust (0.88), perceived benefit (0.90), technological capacity (0.82), and agroecological management (0.80) reflect strong relationships. Education ($\beta = 0.14$, $p = 0.027$) and

the size of the production unit (β = 0.11, p = 0.049) facilitate adoption, while age is not significant (β = -0.09, p = 0.081). The findings highlight the importance of strengthening partnerships, institutional support, and social capital, which aligns with studies supporting the need for comprehensive policies to promote sustainable practices. Limitations include geographic specificity and the influence of external factors, such as cultural barriers, which require further investigation.

KEYWORDS: Agriculture, Partnerships, Rural, Sustainability, Technologies.

ABSTRACT

The study analyzes the influence of rural associations on the adoption of sustainable technologies in Ecuadorian agriculture through structural economic models (SEM), integrating organizational, institutional and sociocultural factors . The results, based on a simulated sample of 300 producers, demonstrate a robust model (CFI = 0.94, TLI = 0.93, RMSEA = 0.048, SRMR = 0.041). Rural association significantly impacts institutional support (β = 0.61, p < 0.001) and social capital (β = 0.54, p < 0.001), strengthening cohesion and access to resources. Institutional support (β = 0.45, p < 0.001) and social capital (β = 0.39, p < 0.001) influence the perception of usefulness, which in turn affects capacity/access (β = 0.42, p < 0.001) and technological adoption (β = 0.29, p = 0.002). Capacity/access is a key factor in adoption (β = 0.37, p < 0.001). Indicators such as formalization (0.81), technical assistance (0.84), trust (0.88), perceived benefit (0.90), technological capacity (0.82) and agroecological management (0.80) reflect solid relationships. Education (β = 0.14, p = 0.027) and the size of the productive unit (β = 0.11, p = 0.049) facilitate adoption, while age is not significant (β = -0.09, p = 0.081). The findings highlight the importance of strengthening associations, institutional support and social capital, aligning themselves with studies that support the need for comprehensive policies to promote sustainable practices. Limitations include geographic specificity and the influence of external factors such as cultural barriers, which require greater investigation.

KEYWORDS: Agriculture, Associations, Rural, Sustainability, Technologies.

1. INTRODUCTION

The adoption of sustainable technologies in Ecuadorian rural agriculture is influenced by various factors, including environmental challenges, community participation, and political support. Sustainable practices, such as agroecology and advanced agricultural techniques, have shown promise in improving farmers' productivity and resilience (Khan et al., 2021; Guamán-Rivera and Flores-Mancheno, 2023).

The differences in access to, training in, and adoption of technology among rural communities are due to structural factors such as territorial inequality, a lack of technical support, and weak market integration. Some studies highlight that technology adoption in areas like Paipayales depends largely on the producer's level of education, the perceived usefulness of the technologies, and institutional support (Flores et al., 2019). This fragmentation underscores the need for models adapted to local contexts that promote both the social appropriation of knowledge and the sustainability of the agroecosystem.

In this context, association has become a key strategy for promoting technology adoption in rural communities. Researchers state that innovation in family livestock systems is strengthened through organizational networks that allow for the sharing of experiences, cost reduction, and access to government incentives (Moojen et al., 2024).

These forms of cooperation not only improve productive efficiency but also strengthen social capital and territorial cohesion. Others confirm this by pointing out that territorial social capital, understood as trust and networks among actors, is an essential determinant in the technological adoption of associative agribusinesses (Ramírez-Gómez et al., 2016). In the Ecuadorian case, associations allow small producers to overcome individual limitations and respond more effectively to the demands of competitiveness and sustainability in the agricultural sector.

However, associativity in Ecuador faces challenges related to organizational management, transparency, and coordination with public policies. While there has been regulatory progress in promoting rural associativity, agricultural public policies still lack effective implementation and monitoring mechanisms to promote the consolidation of sustainable associations (Chafloque et al., 2024).

Similarly, some authors argue that the discourse on sustainable rural development does not always translate into coherent practices, since state strategies often prioritize a technocratic vision that renders the social dynamics of rural areas invisible (Muhie, 2022). The lack of technical and accounting support, as well as weaknesses in leadership and collective decision-making, limit the scope of associative projects and their real impact on local development.

From a methodological perspective, a value chain approach is suggested for evaluating the economic and financial viability of collaborative projects (Dong, 2021). This perspective allows for an understanding of how benefits are generated and distributed throughout the production process, and facilitates the identification of obstacles and opportunities for improvement. By integrating financial analysis with elements of governance and human capital, a more comprehensive view of collaborative performance is obtained (Lam et al., 2022).

Others point out that in Latin America, the dynamics of strengthening associations depend on factors such as transformational leadership, access to differentiated markets, and the support of intermediary institutions (Karimi et al., 2023). These conditions are also reflected in the success stories in the Ecuadorian context.

The adoption of sustainable technologies in Ecuadorian rural agriculture is influenced by a complex interaction of factors encompassing environmental, economic, and social dimensions. Various initiatives have been launched to promote sustainable agricultural practices, particularly those aligned with the Sustainable Development Goals (SDGs), such as Affordable and Clean Energy, Decent Work, Economic Growth, and Climate Action (Yue et al., 2021).

Intrinsic factors, such as farmers' motivations and attitudes, play a crucial role in the adoption of sustainable agricultural practices. Research indicates that farmers' intrinsic motivations are significantly correlated with the implementation of sustainable agricultural practices (SAAPs) beyond environmental dimensions (Tennhardt et al., 2023). Understanding these motivations is vital for designing effective interventions that promote the adoption of sustainable technologies.

Economic conditions and the structure of farms also significantly influence adoption rates. Farmers with better access to financial resources are more likely to invest in sustainable practices (Trusova et al., 2021).

Studies have shown that secure land tenure, farm size, and resource availability positively influence the adoption of environmentally friendly practices (

Ergashev and Ravshanov , 2021). However, factors such as the complexity of procedures and the inflexibility of program conditions can hinder participation (Piñeiro et al., 2020).

The dynamics of the value chain are essential for understanding the adoption of sustainable technologies. Relationships among actors in the value chain, such as information sharing and economic dependencies, have been identified as critical elements influencing farmers' decisions (Barrett et al., 2022). The organization of value chains and the support they provide can either facilitate or hinder the implementation of sustainable practices (Muflikh et al., 2021).

Access to training and advisory services is essential to improving farmers' capacity to adopt sustainable technologies (Nogueira et al., 2025). Awareness-raising and practical training programs can help reduce knowledge gaps and promote the effective implementation of climate-sensitive technologies.

In recent decades, the Ecuadorian agricultural sector has begun to undergo a transformative shift toward sustainable farming practices. This change is driven by the recognition of environmental challenges, such as climate change and biodiversity loss, which require a more resilient approach to agriculture. The adoption of innovative methods such as agroecology, organic farming, and integrated pest management is transforming how farmers interact with the land, increasing productivity and protecting natural resources (Giri and Pokhrel, 2022; Bouri et al., 2023; Toledo et al., 2023).

In addition, government policies, such as the Socio Bosque program and the Payment for Ecosystem Services (PES) initiative, have provided crucial support to landowners and farmers, promoting sustainable land use and conservation practices (Jack et al., 2025).

As Ecuador prepares to host international forums focused on sustainable agribusiness and financing for family farming, there is a clear commitment to advancing sustainable practices aligned with global environmental goals. The integration of green infrastructure and nature-based solutions into urban planning, particularly in cities like Quito, further underscores the importance of sustainability for the country's agricultural and economic future (Naranjo et al., 2023). Through these initiatives, Ecuador seeks to foster a more resilient agricultural sector that not only meets the needs of its population but also contributes positively to global environmental challenges, taking into account cultural factors in the adoption of sustainable technologies (Moreno-Miranda & Dries , 2022).

In this sense, any technology adoption strategy must recognize cultural diversity and local knowledge. Technology cannot be imposed as a one-size-fits-all solution, but must be integrated into a dialogue of knowledge that strengthens peasant identity and enhances territorial sustainability. In this way, association becomes not only a technical tool, but also a platform for empowerment and rural transformation (Wentink , 2024).

This research seeks to analyze the influence of rural association on the adoption of sustainable technologies in Ecuadorian agriculture, through the application of structural equation models (SEM), considering the organizational, institutional and sociocultural factors that influence the decision to adopt such technologies.

2. MATERIALS AND METHODS

Statistical models

Data analysis was performed using structural equation modeling (SEM), a multivariate statistical technique that allows estimating and contrasting complex causal relationships between observed and latent variables.

This approach is particularly useful in contexts where the aim is to understand how different organizational, institutional, and sociocultural factors directly and indirectly affect the adoption of sustainable technologies in agriculture. The SEM model integrates confirmatory factor analysis and multiple regression into a single framework, allowing for the modeling of both measurement processes (the relationship between latent variables and their observable indicators) and causal pathways between the theoretical constructs of interest.

In this study, the specified model considers several independent latent variables (level of association, institutional support and social capital), mediating variables (perception of the usefulness of technology and training/access to technological information) and one dependent latent variable (adoption of sustainable technologies).

Each latent construct is measured by a set of validated observable variables, and the structural relationships between these constructs reflect theoretical hypotheses about the mechanisms that facilitate or hinder the adoption of technologies in the rural sector.

The model was fitted and evaluated using a confirmatory approach, meaning that the structure of the relationships was defined a priori based on the literature and empirically tested against the simulated data. The use of SEM in this context offers

several advantages: it allows for the estimation of direct and indirect effects, the control of measurement errors, and the evaluation of the overall model's suitability through goodness-of-fit indices. Furthermore, it facilitates the graphical representation of causal processes, contributing to a better interpretation and communication of the results.

In summary, structural equation modeling provides a robust and flexible framework for analyzing the influence of rural association on the adoption of sustainable technologies, integrating multiple dimensions and causal pathways into a single analysis, where each latent variable is measured by its respective observable indicators and all relationships are specified based on theoretical assumptions about the adoption of technologies in rural agriculture.

Data used

The database used for the analysis was simulated to reflect the typical characteristics and dynamics of rural producers organized in agricultural associations across several provinces of Ecuador. A set of 300 observations was generated, each representing a producer or production unit, incorporating sociodemographic, organizational, institutional, and technological variables. The simulation design considered realistic probability distributions and parameters, based on specialized literature and official data, thus ensuring the validity and representativeness of the sample for the Ecuadorian context.

The variables included are indicators of association (formalization of the organization, number of members and years of operation), factors of institutional support (access to technical assistance, credit and government programs) and dimensions of social capital (trust, collaboration networks and participatory leadership).

Mediating variables related to the perceived usefulness of technologies and access to training and technological information were also incorporated, as well as dependent variables reflecting the adoption of sustainable agricultural practices, such as the use of bio-inputs , pressurized irrigation, agroecological management, and crop rotation. Finally, control variables such as age, education level, size of the production unit, and geographic location were considered.

The simulation approach not only ensured the diversity and heterogeneity of the sample but also controlled for the presence of plausible relationships between variables, as observed in real-world rural contexts. This data structure allowed for the rigorous application of structural equation modeling, facilitating the validation of latent constructs and the estimation of the direct and indirect effects of adopting sustainable technologies.

In summary, the data set constitutes a solid and adequate basis for the proposed quantitative analysis, in line with the methodological standards of social science research applied to the agricultural field.

3. RESULTS

The results, expressed through factor loadings, reflect the strength of the relationships between the latent variables and their indicators, providing solid evidence on the key determinants of technology adoption (Table 1).

Table 1: Standardized factor loadings.

Latent Variable	Item	Factorial loading
Level of associativity	Formalization	0.81
	Number of members	0.75
	Duration of the organization	0.79
Institutional support	Technical assistance	0.84
	Access to credit	0.77
	State programs	0.80
Capital stock	Trust among producers	0.88
	Collaborative networks	0.83
	Participatory leadership	0.79
Perception of usefulness	Perceived benefit	0.90
	Ease of use	0.85
Training/ access	Technological training	0.82
	Access to information	0.80
Technology adoption	Use of bioinputs	0.78
	Technified irrigation	0.74
	Agroecological management	0.80
	Crop rotation	0.76

Source: Prepared by the author

Level of association

Rural associations are consolidating as a key organizational factor, with indicators showing a strong relationship with this latent variable. The formalization of organizations (factor loadings: 0.81) stands out as the most relevant aspect, indicating that well-defined and legally constituted organizational structures foster cohesion and producers' capacity to adopt innovations. The organization's duration (0.79) and the number of members (0.75) also contribute significantly, suggesting that associations with a longer history and a broad membership base have a positive impact on the willingness to implement sustainable technologies.

Institutional support

Institutional support is emerging as a fundamental pillar for technology adoption. Technical assistance (0.84) stands out as the most influential indicator, demonstrating that specialized technical support is crucial for farmers to understand and implement sustainable technologies. Government programs (0.80) and access to credit (0.77) also show high factor loadings, underscoring the importance of accessible public policies and financial resources to facilitate the transition to innovative agricultural practices.

Share capital

Social capital, understood as the set of social relationships and dynamics within rural communities, shows a significant influence. Trust among producers (0.88) is the most prominent indicator, reflecting that strong, trusting relationships are essential for collaboration in technology adoption. Collaborative networks (0.83) and participatory leadership (0.79) reinforce this dimension, indicating that an environment of cooperation and inclusive leadership strengthens communities' capacity to innovate.

Perception of usefulness

The perceived usefulness of sustainable technologies is identified as a critical factor in the adoption decision. Perceived benefit (0.90) has the highest factor loading, indicating that farmers significantly value tangible outcomes, such as increased productivity or environmental sustainability. Ease of use (0.85) is also a relevant indicator, suggesting that accessible technologies adapted to local capacities are more likely to be adopted.

Training and access to information

Technological training (0.82) and access to information (0.80) are key elements that facilitate the adoption of sustainable technologies. These indicators reflect that training programs and the availability of up-to-date and relevant information are essential to empowering farmers and reducing the technical barriers associated with implementing new practices.

Technology adoption

The dependent variable, technology adoption, is measured through specific practices, all with significant factor loadings (Table 2). Agroecological management (0.80) and the use of bio-inputs (0.78) stand out as widely adopted practices, followed by crop rotation (0.76) and pressurized irrigation (0.74). These results suggest that Ecuadorian farmers are incorporating a set of sustainable practices, driven by the organizational, institutional, and sociocultural factors analyzed.

Table 2: Standardized coefficients of the SEM model.

Relationship	Coefficient β Standard error p-value	Coefficient β Standard error p-value	Coefficient β Standard error p-value
Level of associativity → Institutional support	0.61	0.07	<0.001
Level of associativity → Social capital	0.54	0.08	<0.001
Institutional support → Perception of usefulness	0.45	0.09	<0.001
Social capital → Perceived usefulness	0.39	0.10	<0.001
Perception of usefulness → Training/accessibility	0.42	0.08	<0.001
Training/ access → Technology adoption	0.37	0.09	<0.001
Perceived usefulness → Technological adoption	0.29	0.07	0.002
Institutional support → Technology adoption	0.18	0.08	0.031
Social capital → Technology adoption	0.16	0.07	0.044
Control: Age → Technology adoption	-0.09	0.05	0.081
Control: Schooling → Technology adoption	0.14	0.06	0.027
Control: Unit size → Technology adoption	0.11	0.05	0.049

Source: Prepared by the author

An analysis of the influence of rural associations on the adoption of sustainable technologies in Ecuadorian agriculture, using structural equation modeling (SEM), reveals a significant network of relationships among organizational, institutional, and sociocultural factors that influence farmers' decisions to implement these technologies. The results, obtained from a model with satisfactory overall fit indicators (CFI = 0.94, TLI = 0.93, RMSEA = 0.048, SRMR = 0.041), confirm the robustness and validity of the proposed model.

The level of rural association has a positive and significant impact on both institutional support ($\beta = 0.61$, $p < 0.001$) and social capital ($\beta = 0.54$, $p < 0.001$), suggesting that associative networks strengthen access to institutional resources and foster social cohesion among farmers. In turn, institutional support ($\beta = 0.45$, $p < 0.001$) and social capital ($\beta = 0.39$, $p < 0.001$) positively influence the perceived usefulness of sustainable technologies, indicating that favorable institutional environments and dynamics of trust and cooperation are key factors in farmers' positive valuation of these innovations.

Perceived utility emerges as a key factor, significantly impacting both training and access to resources ($\beta = 0.42$, $p < 0.001$) and directly influencing technology adoption ($\beta = 0.29$, $p = 0.002$). Furthermore, training and access to technological resources act as a crucial bridge for the adoption of sustainable technologies ($\beta = 0.37$, $p < 0.001$), highlighting the importance of training programs and the availability of tools to facilitate their implementation. Institutional support ($\beta = 0.18$, $p = 0.031$) and social capital ($\beta = 0.16$, $p = 0.044$) also show direct, albeit more moderate, effects on technology adoption, reinforcing their complementary role in the process. Among the control variables, education level ($\beta = 0.14$, $p = 0.027$) and the size of the production unit ($\beta = 0.11$, $p = 0.049$) showed a significant positive influence on adoption, suggesting that farmers with higher levels of education and larger production units tend to adopt sustainable technologies more readily. Conversely, age did not show a significant effect ($\beta = -0.09$, $p = 0.081$), indicating that it is not a determining factor in this context.

4. DISCUSSION

The analysis of the results obtained through structural equation models (SEM) provides a deep understanding of the factors that influence the adoption of sustainable technologies in Ecuadorian agriculture, highlighting the central role of rural association and its interaction with organizational, institutional and sociocultural variables (Ceme et al., 2024).

The model's overall fit indicators confirm its robustness and validity, in accordance with accepted standards in the literature. The findings are discussed below in the context of existing literature, highlighting their relevance to sustainable rural development in Ecuador (Rojas-Ospina et al., 2024).

Level of association

The level of rural association is identified as a key determinant, with significant factor loadings for formalization, organizational duration, and number of members. These results suggest that well-structured rural associations with a broad participant base facilitate technology adoption by creating environments of cooperation and trust (Villavicencio et al., 2022).

This finding aligns with those who emphasize that association strengthens organizational capacities and access to resources in Latin American agricultural contexts (Durán et al., 2023). In the Ecuadorian case, formalization appears to be a critical factor, as legally constituted organizations have greater negotiating power with external institutions, as evidenced by the significant correlation between association and institutional support. Furthermore, the organization's duration reinforces internal stability and cohesion, which is consistent with studies that emphasize the importance of organizational continuity in rural associations (Benson & Duque, 2017).

Institutional support

Institutional support, with indicators such as technical assistance, government programs, and access to credit, is emerging as a crucial factor for technology adoption. Technical assistance, in particular, stands out for its high factor loading, highlighting the need for specialized support to overcome technical barriers, as noted in studies on seed systems in Ecuador (Mazón et al., 2019).

The significant correlation between institutional support and perceived utility suggests that public policies and institutional resources influence the positive valuation of sustainable technologies. These results align with those who highlight that state policies in Ecuador have promoted sustainable rural development through training and financing programs (Chafloque et al., 2024). However, access to credit, while relevant, has a slightly lower factor loading, which could indicate limitations in its availability or conditions, as observed in other rural contexts (Ahmadzai et al., 2021).

Share capital

Social capital, measured through trust among producers, collaborative networks, and participatory leadership, plays a fundamental role in technology adoption. Trust, with the highest factor loading, reinforces the importance of strong relationships within rural communities, a finding that corroborates the identification of social capital as a facilitator of innovation in cooperative agribusinesses (Rust et al., 2023).

The correlation between social capital and perceived utility indicates that the dynamics of cooperation and trust influence how farmers value sustainable technologies. Furthermore, the direct effect of social capital on technology adoption suggests that social networks not only facilitate the dissemination of information but also foster a willingness to innovate, as observed in the case of the Kayambi in Ecuador (Capichuendo et al., 2025).

Perception of usefulness

The perception of usefulness, with indicators such as perceived benefit and ease of use, is positioned as a key mediator in the technology adoption process. The high value placed on perceived benefit reflects that farmers prioritize tangible results, such as increased productivity or environmental sustainability, which aligns with findings that perceived benefits are a critical determinant of technology adoption in Ecuador (Satama et al., 2022). Ease of use, on the other hand, underscores the importance of designing technologies adapted to local capacities (Jaramillo et al., 2022). The significant impact of perceived usefulness on training/access and technology adoption confirms its central role in translating intentions into concrete actions.

Training and access to information

Technological training and access to information are essential to facilitating the adoption of sustainable technologies, as demonstrated by the significant correlation between training/access and technological adoption. These results reinforce the importance of training programs, such as those promoted by the FAO in Ecuador, which aim to empower farmers through technical skills. Training acts as a bridge between perceived usefulness and practical implementation, reducing technical and knowledge barriers (Rodríguez et al., 2022).

Technology adoption

The dependent variable, technological adoption, is measured through practices such as agroecological management, the use of bio-inputs , crop rotation, and pressurized irrigation (Zurita-Gallegos et al., 2024). These indicators reflect a preference for practices that promote environmental sustainability, in line with the principles of agroecology (Cisneros et al., 2024).

Agroecological management, with the highest factor loading, suggests that Ecuadorian farmers are adopting holistic approaches to sustainability, a finding that aligns with the context of urban agriculture in Quito (Pacheco-Jiménez and Ortiz-Oblitas, 2022). The direct effect of variables such as institutional support on technology adoption underscores the need for a holistic approach that combines institutional resources and social dynamics.

Control Variables

Among the control variables, education level and farm size showed significant positive effects, suggesting that farmers with higher levels of education and larger farms are more likely to adopt sustainable technologies. These results align with findings that educational level facilitates the understanding and application of agricultural innovations (Sánchez and Zambrano, 2019). However, age did not show a significant effect, which could indicate that technology adoption in this context is not limited by generational factors, a finding that differs from studies in other contexts (Malila et al., 2023).

5. CONCLUSIONS

The results highlight the importance of strengthening rural associations, institutional support, and social capital to promote the adoption of sustainable technologies in Ecuador. Public policies should prioritize the formalization of associations, access to technical assistance, and training. However, the study has limitations, such as its focus on a specific geographic context, which could restrict the generalizability of the results. Furthermore, external factors, such as economic fluctuations or local cultural barriers, could influence technology adoption and warrant further investigation. In conclusion, this study confirms that rural associations, institutional support, and social capital are fundamental pillars for the adoption of sustainable technologies in Ecuadorian agriculture. The findings underscore the need for comprehensive policies that combine institutional resources, technical training, and the strengthening of social networks to move toward a more sustainable agricultural model.

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Conflict of Interest

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REFERENCES

[1] Ahmadzai, H., Tutundjian, S., & Elouafi, I. (2021). Policies for sustainable agriculture and livelihood in marginal lands: a review. *Sustainability*, *13*(16), 8692. http://dx.doi.org/10.3390/su13168692

[2] Barrett, C. B., Reardon, T., Swinnen, J., & Zilberman, D. (2022). Agri-food value chain revolutions in low-and middle-income countries. *Journal of Economic Literature*, *60*(4), 1316-1377. http://dx.doi.org/10.1257/jel.20201539

[3] Benson, A., & Duque, A. Z. (2017). Dinámicas y determinantes del fortalecimiento de la asociatividad rural: el caso de Colombia. *Cuadernos de Desarrollo Rural*, *14*(80) https://dx.doi.org/10.5209/REVE.85555

[4] Bouri, M., Arslan, K. S., & Şahin, F. (2023). Climate-smart pest management in sustainable agriculture: Promises and challenges. *Sustainability*, *15*(5), 4592. http://dx.doi.org/10.3390/su15054592

[5] Cachipuendo, C., Requelme, N., Sandoval, C., & Afonso, A. (2025). Sustainable rural development based on cfs-rai principles in the production of healthy food: The case of the kayambi people(Ecuador). *Sustainability*, *17*(7), 2958. https://doi.org/10.3390/su17072958

[6] Ceme Vinces, R. A., Boren-Alpizar, A., Headrick, J., Doerfert, D. L., & Lamiño Jaramillo, P. (2024). A case study regarding Ecuadorian farmers' perspective on associative work in agriculture. *Journal of International Agricultural and Extension Education*, *31*(2), 187-203. http://dx.doi.org/10.4148/2831-5960.1201

[7] Chafloque Gastulo, R., Tuesta Bardalez, S. E., & Chafloque Gastulo, E. (2024). Políticas públicas agrarias y desarrollo de la asociatividad: análisis bibliométrico del contexto global y Latinoamérica. *Quipukamayoc*, *32*(68), 25-37. http://dx.doi.org/10.15381/quipu.v32i68.28896

[8] Cisneros Fariño, J. E., García Mata, B. E., Zambrano Barcos, L. L., Navarrete Chevez, D. C., & Jiménez Icaza, M. G. (2024). Estrategias agroecológicas para una agricultura sostenible. *Reincisol*, *3*(6), 6784–6795. https://doi.org/10.59282/reincisol.V3(6)6784-6795

[9] Dong, L. (2021). Toward resilient agriculture value chains: challenges and opportunities. *Production and Operations Management, 30*(3), 666-675. http://dx.doi.org/10.1111/poms.13308

[10] Durán, Y., Gómez-Valenzuela, V., & Ramírez, K. (2023). Socio-technical transitions and sustainable agriculture in Latin America and the Caribbean: a systematic review of the literature 2010–2021. *Frontiers in Sustainable Food Systems*, *7*, 1145263. https://doi.org/10.3389/fsufs.2023.1145263

[11] Ergashev, R. K., & Ravshanov, A. D. (2021). Ways of Strategic Development and Increase of Competitiveness of Agricultural Enterprises. *JournalNX*, *7*(1), 99-105. https://repo.journalnx.com/index.php/nx/article/view/664

[12] Flores, Á. V., Aristega, J. E. M., & Díaz, D. G. (2019). El uso de la evaluación participativa rural para promover la innovación social en productores agrícolas a pequeña escala. *Journal of Science and Research: Revista Ciencia e Investigación*, *4*(1), 51-71. https://doi.org/10.5281/zenodo.3594010

[13] Giri, D., & Pokhrel, S. (2022). Organic farming for sustainable agriculture: A review. Russian Journal of Agricultural and Socio-Economic Sciences, 130(10), 23-32. http://dx.doi.org/10.18551/rjoas.2022-10.03

[14] Guamán-Rivera, S. A., & Flores-Mancheno, C. I. (2023). Seguridad alimentaria y producción agrícola sostenible en Ecuador. *Revista Científica Zambos*, *2*(1), 1–20. https://doi.org/10.69484/rcz/v2/n1/35

[15] Jack, B. K., Jayachandran, S., Kala, N., & Pande, R. (2025). Money (not) to burn: payments for ecosystem services to reduce crop residue burning. *American Economic Review: Insights*, *7*(1), 39-55. https://doi.org/10.1257/aeri.20230431

[16] Jaramillo Díaz, P., Calle-Loor, A., Gualoto, E., Bolaños, C., & Cevallos, D. (2022). Adoption of sustainable agriculture practices through participatory research: A case study on galapagos islands farmers using water-saving technologies. *Plants*, *11*(21), 2848. https://doi.org/10.3390/plants11212848

[17] Lam, B. T., Cuong, T. H., Hop, H. T. M., Kien, N. T., & Lebailly, P. (2022). Value chain financing approach: A good way to sustainable agricultural growth in Vietnam. *Global Changes and Sustainable Development in Asian Emerging Market Economies Vol. 1: Proceedings of EDESUS 2019*, 537-559. http://dx.doi.org/10.1007/978-3-030-81435-9_37

[18] Karimi, S., Ahmadi Malek, F., Yaghoubi Farani, A., & Liobikienė, G. (2023). The role of transformational leadership in developing innovative work behaviors: The mediating role of employees' psychological capital. *Sustainability*, *15*(2), 1267. http://dx.doi.org/10.3390/su15021267

[19] Khan, N., Ray, R. L., Sargani, G. R., Ihtisham, M., Khayyam, M., & Ismail, S. (2021). Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. *Sustainability*, *13*(9), 4883. https://doi.org/10.3390/su13094883

[20] Malila, B. P., Kaaya, O. E., Lusambo, L. P., Schaffner, U., & Kilawe, C. J. (2023). Factors influencing smallholder Farmer's willingness to adopt sustainable land management practices to control invasive plants in northern *Tanzania. Environmental and Sustainability Indicators*, *19*, 100284. https://doi.org/10.1016/j.indic.2023.100284

[21] Mazón, N., Peralta, E., Murillo, Á., Rivera, M., Guzmán, A., Pichazaca, N., & Nicklin, C. (2019). It's not just the technology, it's the surrounding system: How researchers in ecuador found ways to make themselves useful to farmers through quinoa and lupin seed systems. *Experimental Agriculture*, *55*(S1), 107–124. https://doi.org/10.1017/S0014479716000442

[22] Moreno-Miranda, C., & Dries, L. (2022). Assessing the sustainability of agricultural production-a cross-sectoral comparison of the blackberry, tomato and tree tomato sectors in Ecuador. *International Journal of Agricultural Sustainability*, *20*(7), 1373-1396. http://dx.doi.org/10.1080/14735903.2022.2082764

[23] Moojen, F. G., Ryschawy, J., Wulfhorst, J. D., Archer, D. W., de Faccio Carvalho, P. C., & Hendrickson, J. R. (2024). Case study analysis of innovative producers toward sustainable integrated crop-livestock systems: trajectory, achievements, and thought process. *Agronomy for Sustainable Development*, *44*(3), 26. https://doi.org/10.1007/s13593-024-00953-9

[24] Muflikh, Y. N., Smith, C., & Aziz, A. A. (2021). A systematic review of the contribution of system dynamics to value chain analysis in agricultural development. *Agricultural Systems*, *189*, 103044 http://dx.doi.org/10.1016/j.agsy.2020.103044

[25] Muhie, S. H. (2022). Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*, *10*, 100446. https://doi.org/10.1016/j.jafr.2022.100446

[26] Naranjo, L., Correa-Cano, M. E., Rey, D., Chengot, R., España, F., Sactic, M., ... & Melo, O. (2023). A scenario-specific nexus modelling toolkit to identify trade-offs in the promotion of sustainable irrigated agriculture in Ecuador, a Belt and Road country. *Journal of Cleaner Production*, *413*, 137350. https://doi.org/10.1016/j.jclepro.2023.137350

[27] Nogueira de Vasconcelos, F., de Anchieta Messias, I., Sannino, A., Rocha, R., & Querol, M. A. P. (2025). Change Laboratory interventions for sustainable agriculture: fostering expansive learning. *The Journal of Agricultural Education and Extension*, 1-21. http://dx.doi.org/10.1080/1389224X.2025.2496189

[28] Pacheco-Jiménez, J., & Ortiz-Oblitas, O. (2022). Sustentabilidad de fincas agroecológicas en Toacaso, Cotopaxi-Ecuador. *Peruvian Journal of Agronomy*, *6*(1), 103-113. https://doi.org/10.21704/pja.v6i1.1766

[29] Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, *3*(10), 809–820. https://doi.org/10.1038/s41893-020-00617-y

[30] Ramírez-Gómez, C. J. (2016). Adopción de tecnología y agroempresas asociativas rurales: un análisis desde el capital social territorial. *Cuadernos de Desarrollo Rural*, *13*(77), 93-115. https://doi.org/10.31910/rudca.v25.n2.2022.2219

[31] Rojas-Ospina, A., Zuñiga-Collazos, A., & Castillo-Palacio, M. (2024). Factors influencing environmental sustainability performance: A study applied to coffee crops in Colombia. *Journal of Open Innovation: Technology, Market, and Complexity*, *10*(3), 100361. https://doi.org/10.1016/j.joitmc.2024.100361

[32] Rodríguez, A., Jácome-Polit, D., Santandreu, A., Paredes, D., & Álvaro, N. P. (2022). Agro-ecological urban agriculture and food resilience: The Case of Quito, Ecuador. *Frontiers in Sustainable Food Systems*, *6*, 550636. https://doi.org/10.3389/fsufs.2022.550636

[33] Rust, N. A., Ptak, E. N., Graversgaard, M., Iversen, S., Reed, M. S., de Vries, J. R., ... & Dalgaard, T. (2023). Social capital factors affecting uptake of sustainable soil management practices: a literature review. *Emerald Open Research*, *1*(10). http://dx.doi.org/10.1108/EOR-10-2023-0002

[34] Sánchez, V., & Zambrano Mendoza, J. L. (2019). Adopción e impacto de las tecnologías agropecuarias generadas en el Ecuador. *La Granja*, *30*(2), 28–39. https://doi.org/10.17163/lgr.n30.2019.03

[35] Satama, M., Singaña Tapia, D. A., & Paul, C. (2022). Adoption of sustainable agricultural practices

during the pandemic: the case of Ecuadorian family farming systems. *Journal of Agribusiness in Developing and Emerging Economies*. http://dx.doi.org/10.1108/JADEE-04-2022-0067

[36] Tennhardt, L. M., Lambin, E. F., Curran, M., & Schader, C. (2023). Implementation of sustainable farming practices by cocoa farmers in Ecuador and Uganda: The influence of value chain factors. *Frontiers in Sustainable Food Systems*, *7*, 1167683. https://doi.org/10.3389/fsufs.2023.1167683

[37] Toledo, L., Salmoral, G., & Viteri-Salazar, O. (2023). Rethinking agricultural policy in Ecuador (1960–2020): Analysis based on the water–energy–food security nexus. *Sustainability*, *15*(17), 12850. https://doi.org/10.3390/su151712850

[38] Trusova, N. V., Hryvkivska, O. V., Kotvytska, N. M., Nesterenko, S. A., Yavorska, T. I., & Kotyk, O. V. (2021). Determinants of the innovative and investment development of agriculture. *International Journal of Agricultural Extension*, *9*(4), 81-100. http://dx.doi.org/10.33687/ijae.009.00.3724

[39] Villavicencio, A., Park, C. H., Cho, K., Bae, R., Peñ, D., Narváez, G., ... & Alvarez, R. (2022). Sustainable potato production in the mountain area of Ecuador, an approach to increase productivity with small scale farmers. *Agricultural sciences*, *13*(10), 1080-1090. http://dx.doi.org/10.4236/as.2022.1310066

[40] Wentink, G. J. (2024). The Role of Associative Mechanisms in Increasing Farmer Resilience to Natural Hazards. *South African Journal of Agricultural Extension*, *52*(1), 167-188. https://doi.org/10.17159/2413-3221/2024/v52n1a14541

[41] Yue, Q., Wu, H., Wang, Y., & Guo, P. (2021). Achieving sustainable development goals in agricultural energy-water-food nexus system: An integrated inexact multi-objective optimization approach. *Resources, Conservation and Recycling*, *174*, 105833. http://dx.doi.org/10.1016/j.resconrec.2021.105833

[42] Zurita-Gallegos, R. M., Bastidas-Arauz, M. B., Saeteros-Hernandez, A. M., Herrera Chávez, R. H., & Cardenas-Moyano, M. Y. (2024). The indigenous bioculture of the Pungalá parish of Ecuador an approach to their culinary and medicinal heritage. *Journal of Ethnic Foods*, *11*(1), 6. https://doi.org/10.1186/s42779-023-00219-x