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Interactive Agritourism as a Pathway to Sustainable Socioeconomic Development in Amazonian Indigenous Communities: A Pilot Optimization Model

El agroturismo interactivo como camino hacia el desarrollo socioeconómico sostenible en las comunidades indígenas amazónicas: un modelo piloto de optimización

O agroturismo interativo como caminho para o desenvolvimento socioeconômico sustentável nas comunidades indígenas amazônicas: um modelo piloto de otimização

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ABSTRACT

Introduction: Interactive agritourism has emerged as a promising pathway to strengthen sustainable livelihoods in indigenous Amazonian communities, yet empirical evidence on how to implement equitable models remains limited. This study evaluates the socioeconomic potential of agritourism in the native community of Tsuntsuntsa (Amazonas, Peru) through an integrated methodological approach. Materials and methods: The research employed a mixed methodology combining household surveys (n=121, 100% of households), participatory diagnosis, and multi-objective optimization modeling. Structured surveys assessed willingness to participate, economic expectations, and infrastructure conditions (Likert scale, Cronbach's α=0.91). A linear programming model was developed to maximize net community benefit, incorporating the Gini coefficient as a secondary objective to measure income distribution inequality. Results: Survey data revealed strong community support for agritourism (92% agreed on benefits) but heterogeneous levels of readiness (only 41% considered their household prepared). The optimization model demonstrated that increasing available budgets from 800 to 1,200 units expanded household participation from 8 to 10 and increased total benefits from 14,000 to 16,950 units, with only moderate impacts on equity (Gini coefficient = 0.27–0.30). Perceived global impact was rated high by 50% of respondents, while adequate local implementation was rated low by 40%. The proposed pilot model integrates governance structures, household selection criteria (based on Gini optimization), visitor experience components (agricultural demonstrations, cultural practices, gastronomy, ecological walks), and capacity-building strategies. Discussion: The findings align with global literature indicating that agritourism can diversify income and boost resilience, while the Gini-based optimization addresses the critical trade-off between efficiency and equity in community-based tourism. Conclusions: Interactive agritourism represents a viable and equitable development opportunity for Tsuntsuntsa, provided that implementation is accompanied by phased inclusion, infrastructure investments, and strengthened community governance.

Keywords: Gini coefficient; equity and efficiency; sustainable livelihoods; Amazon region; participatory diagnosis; rural

development.

RESUMEN

Introducción: El agroturismo interactivo ha surgido como una vía prometedora para fortalecer los medios de vida sostenibles en las comunidades indígenas amazónicas, pero la evidencia empírica sobre cómo implementar modelos equitativos sigue siendo limitada. Este estudio evalúa el potencial socioeconómico del agroturismo en la comunidad nativa de Tsuntsuntsa (Amazonas, Perú) a través de un enfoque metodológico integrado. Materiales y métodos: La investigación empleó una metodología mixta que combina encuestas de hogares (n=121, 100% de los hogares), diagnóstico participativo y modelos de optimización multiobjetivo. Las encuestas estructuradas evaluaron la voluntad de participar, las expectativas económicas y las condiciones de la infraestructura (escala de Likert, α de Cronbach = 0,91). Se desarrolló un modelo de programación lineal para maximizar el beneficio neto de la comunidad, incorporando el coeficiente de Gini como objetivo secundario para medir la desigualdad en la distribución del ingreso. Resultados: Los datos de la encuesta revelaron un fuerte apoyo comunitario al agroturismo (92% estuvo de acuerdo en los beneficios), pero niveles heterogéneos de preparación (sólo el 41% consideró que su hogar estaba preparado). El modelo de optimización demostró que aumentar los presupuestos disponibles de 800 a 1200 unidades amplió la participación de los hogares de 8 a 10 y aumentó los beneficios totales de 14 000 a 16 950 unidades, con impactos sólo moderados en la equidad (coeficiente de Gini = 0,27-0,30). El impacto global percibido fue calificado como alto por el 50% de los encuestados, mientras que la implementación local adecuada fue calificada como baja por el 40%. El modelo piloto propuesto integra estructuras de gobernanza, criterios de selección de hogares (basados en la optimización de Gini), componentes de la experiencia de los visitantes (demostraciones agrícolas, prácticas culturales, gastronomía, caminatas ecológicas) y estrategias de desarrollo de capacidades. Discusión: Los hallazgos se alinean con la literatura global que indica que el agroturismo puede diversificar los ingresos y aumentar la resiliencia, mientras que la optimización basada en Gini aborda el equilibrio crítico entre eficiencia y equidad en el turismo comunitario. Conclusiones: El agroturismo interactivo representa una oportunidad de desarrollo viable y equitativa para Tsuntsuntsa, siempre que su implementación vaya acompañada de una inclusión gradual, inversiones en infraestructura y una gobernanza comunitaria fortalecida.

Palabras clave: coeficiente de Gini; equidad y eficiencia; medios de vida sostenibles; región amazónica; diagnóstico participativo; desarrollo rural.

RESUMO

Introdução: O agroturismo interativo emergiu como um caminho promissor para fortalecer os meios de subsistência sustentáveis nas comunidades indígenas amazônicas, mas as evidências empíricas sobre como implementar modelos equitativos permanecem limitadas. Este estudo avalia o potencial socioeconômico do agroturismo na comunidade nativa de Tsuntsuntsa (Amazonas, Peru) através de uma abordagem metodológica integrada. Materiais e métodos: A pesquisa empregou uma metodologia mista combinando pesquisas domiciliares (n=121, 100% dos domicílios), diagnóstico participativo e modelagem de otimização multiobjetivo. Os inquéritos estruturados avaliaram a vontade de participar, as expectativas económicas e as condições de infraestrutura (escala Likert, α de Cronbach=0,91). Foi desenvolvido um modelo de programação linear para maximizar o benefício líquido para a comunidade, incorporando o coeficiente de Gini como objectivo secundário para medir a desigualdade na distribuição do rendimento. Resultados: Os dados do inquérito revelaram um forte apoio comunitário ao agroturismo (92% concordaram com os benefícios), mas níveis heterogéneos de preparação (apenas 41% consideraram o seu agregado familiar preparado). O modelo de otimização demonstrou que o aumento dos orçamentos disponíveis de 800 para 1.200 unidades expandiu a participação das famílias de 8 para 10 e aumentou os benefícios totais de 14.000 para 16.950 unidades, com impactos apenas moderados na equidade (coeficiente de Gini = 0,27–0,30). O impacto global percebido foi classificado como alto por 50% dos entrevistados, enquanto a implementação local adequada foi classificada como baixa por 40%. O modelo piloto proposto integra estruturas de governação, critérios de selecção de agregados familiares (baseados na optimização de Gini), componentes de experiência do visitante (demonstações agrícolas, práticas culturais, gastronomia, caminhadas ecológicas) e estratégias de capacitação. Discussão: As conclusões estão alinhadas com a literatura mundial que indica que o agroturismo pode diversificar os rendimentos e aumentar a resiliência, enquanto a otimização baseada em Gini aborda o compromisso crítico entre eficiência e equidade no turismo comunitário. Conclusões: O agroturismo interactivo representa uma oportunidade de desenvolvimento viável e equitativa para Tsuntsuntsa, desde que a implementação seja acompanhada por uma inclusão faseada, investimentos em infra-estruturas e uma governação comunitária reforçada.

Palavras-chave: Coeficiente de Gini; equidade e eficiência; meios de subsistência sustentáveis; região amazônica; diagnóstico participativo; desenvolvimento rural.

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Introduction

Tourism has increasingly been recognized as a strategic sector to foster sustainable development, particularly in rural and indigenous territories (Lane, 2005; Scheyvens et al., 2021). Beyond its economic contribution, tourism can generate significant sociocultural and environmental benefits when designed through participatory, community-based models (Giampiccoli & Saayman, 2018; Okazaki, 2008). Within this framework, interactive agritourism—a modality where visitors actively engage with agricultural practices, cultural traditions, and community life—emerges as a promising alternative for diversifying livelihoods in vulnerable regions (Addinsall et al., 2017; Cavalleri et al., 2022). This approach not only creates income opportunities but also strengthens cultural identity and supports environmental stewardship (Knežević et al., 2025; Wen-Ta, 2025). In Latin America, indigenous and rural communities are increasingly exploring agritourism initiatives as mechanisms to integrate sustainable livelihoods with heritage preservation (Espluga-Trenc et al., 2021; Mestanza Ramón & Jiménez Caballero, 2024).

In the Peruvian Amazon, the development of community-based tourism remains incipient and fragmented, often constrained by limited infrastructure, governance challenges, and market access (Zaphiris et al., 2024). Despite these barriers, the Amazonian region holds vast potential due to its cultural richness, biodiversity, and growing demand for experiential tourism that aligns with sustainability principles (Molina et al., 2024). Recent studies have highlighted that tourists are increasingly motivated by authentic experiences linked to food systems, agroecology, and intercultural exchange, making agritourism particularly relevant in indigenous territories (Musa & Chin, 2022).

A critical gap in current research lies in the lack of quantitative models that evaluate both the efficiency and equity of community-based tourism projects (Dangi & Jamal, 2016; Naranjo Llupart, 2022). While most literature focuses on case studies, sociocultural outcomes, or environmental assessments, few studies incorporate optimization approaches to balance economic performance with fair benefit distribution among households (Munasinghe, 2002; Dale, 2000; Cambero & Sowlati, 2014). Addressing inequality within tourism initiatives is especially important in indigenous contexts, where the concentration of benefits in a small group of households can undermine social cohesion and reduce long-term sustainability (Sharpley & Telfer, 2015; Taylor, 2017; Pylypenko et al., 2024; Valdivia & Barbieri, 2014). In this regard, integrating mathematical programming with measures of social equity, such as the Gini index, provides an innovative framework to design inclusive tourism models (Lau et al., 2017; Bakker et al., 2023).

The Gini coefficient is commonly used as a measure of income inequality (Oviedo-García et al., 2019), using the Lorenz curve as its graphical basis (Amin Megat Ali et al., 2024). While it has been widely utilized in global analyses at the country level (Mouratidis, 2006), it can also be applied locally to measure inequalities in income, wealth, and access to services (Jin et al., 2015). The Gini coefficient ranges from 0 to 1: a value of 0 indicates total equality, while a value of 1 reflects complete inequality. According to international standards, a Gini coefficient below 0.3 signifies a particularly equitable state; between 0.3 and 0.4 indicates a normal condition; above 0.4 raises concerns; and above 0.6 indicates a risky situation (Wan et al., 2025). Relating tourism to the Gini coefficient has gained popularity as a means of measuring the distributive impact of this economic activity (Zhang, 2021; Mahadevan et al., 2017).

In pursuit of economic equity through tourism, this research evaluated the potential of interactive agritourism as a model for sustainable socioeconomic development in the native community of Tsuntsuntsa, Amazonas, Peru. The research employs a mixed methodology integrating household surveys, participatory diagnosis, and optimization modeling. This approach aims to identify households at risk, evaluate their current viability, and design an equitable pilot system. By addressing the trade-off between efficiency and equity, the study contributes to the literature on sustainable tourism, illustrating how quantitative tools can aid in participatory planning within indigenous communities. The objective of this article is to present a pilot model of interactive agritourism that maximizes community benefits and guarantees an equitable distribution thereof, through the integration of multi-objective mathematical optimization and participatory diagnosis in the native community of Tsuntsuntsa.

Materials and Methods

Study area

The native community of Tsuntsuntsa (5°23'21.24"S, 78°27'09.81"W) is located in northwestern Peru, in the Amazonas region, Aramango district, on the left bank of the Marañón River (Figure 1). It lies between 300 and 800 meters above sea level. The terrain is undulating to rugged, with hills, river terraces, and areas of primary forest. The community is surrounded by numerous rivers, streams, and springs essential to daily life and production. Among the predominant ecosystems is the Amazonian tropical rainforest, characterized by high floral and faunal biodiversity, endemic species, and natural resources of cultural and ecological value. The climate is humid Amazonian tropical, with an average annual temperature ranging from 22 to 27 °C and annual rainfall between 2,000 and 3,500 mm/year (SENAMHI, 2021). These conditions favor diversified agriculture, agroforestry systems, and ecotourism.

Identification of households with the potential to engage in interactive agritourism

Structured surveys and semi-structured interviews were conducted with all heads of households in the Tsuntsuntsa indigenous community (121 members), representing 100% of the households. The census-based design ensures full population coverage rather than a probabilistic sample. The questions explored their willingness to participate, economic expectations, and the condition of basic infrastructure. Responses were evaluated on a Likert scale ranging from 1 to 5 (Abdalla Mohamed & Reda Hassan Farahat, 2019), and consistency was assessed using normality tests (Ryan–Joiner) (Murairwa, 2022). Statistical analyses were conducted to identify which households were most willing to participate (Alegre et al., 2009; Mugizi et al., 2017). The survey instrument was developed using established frameworks for assessing community-based tourism readiness (Simpson, 2001). Content validity was evaluated by three experts in sustainable tourism and rural development (Choi & Sirakaya, 2005). Internal consistency demonstrated acceptable reliability (Cronbach's $\alpha = 0.91$) (Rheeders & Meyer, 2023). Given the census-based design ($n = 121$), the results reflect the full population of the community, thereby eliminating sampling error.

Current status of agritourism and its socioeconomic viability

A participatory diagnosis was conducted incorporating three sources of information: (i) a documentary review of similar policies and experiences in the Peruvian Amazon, (ii) direct observation of productive activities such as coffee, cocoa, fish farming, and handicrafts, and (iii) community workshops with local leaders. A descriptive and comparative analysis was performed to evaluate perceptions of sustainability, economic impacts, and barriers to implementation (Hussain et al., 2024). The results were organized in matrices outlining strengths and limitations (Wickramasinghe & Takano, 2009).

Modeling the impacts of agritourism

This objective was achieved through mathematical optimization, effectively balancing economic efficiency and social equity. A linear programming model was developed in which each household serves as a decision unit ($x_i \in \{0,1\}$) (Yuan et al., 2017; Ziaabadi et al., 2017). The objective function maximized the net community benefit—defined as potential income ($\alpha p_i c_i$) minus the cost of habilitation (k_i)—subject to constraints on the total budget and the minimum accommodation capacity.

The model was extended to a multi-objective framework incorporating the Gini index as a measure of income distribution inequality, resolving the trade-off between efficiency and equity by employing the weighting method (λ) (Niemi et al., 2025). Household incomes (y_i) were estimated using the function:

$$y_i = \alpha \cdot p_i \cdot c_i \cdot x_i \quad (1)$$

where: p_i = predisposition of the household (Likert scale 1–5); c_i = hosting capacity; x_i = binary selection variable; α = proportionality constant.

The Gini coefficient was calculated as (Lau et al., 2017):

$$G = (\Sigma \Sigma \, |y_i - y_j|) / (2 \cdot n^2 \cdot \bar{y}) \quad (2)$$

where n = number of households; y_i = income of household i; $\bar{y}$ = mean income of all selected households. The R package 'ineq' was used with the function ineq(y, type = 'Gini'). In the model, values ranged from 0.27 to 0.42.

Pilot model for interactive agritourism in Tsuntsuntsa

The quantitative results were integrated with the social diagnosis to create a participatory pilot model (Alberdi-Erice et al., 2021). This model included: (i) the optimal selection of host households, (ii) an assessment

of community benefits and equity levels achieved, and (iii) operational guidelines encompassing minimum infrastructure requirements, hospitality training, and community governance mechanisms. A scalability strategy was developed to support replication in other Amazonian indigenous communities, emphasizing cultural and environmental sustainability (Shaw & da Silva, 2023).

Results

Households with the potential to engage in interactive agritourism

Table 1 summarizes household perceptions regarding participation potential, expected benefits, hosting readiness, and community-level viability of interactive agritourism. Overall, responses indicate strong collective support for agritourism development, particularly regarding expected economic benefits and perceived community viability.

In contrast, perceptions of household-level readiness were more heterogeneous. While a substantial proportion of respondents reported that their households were prepared to host visitors, a notable segment reported limited readiness. The greatest divergence was observed in responses regarding individual participation potential, where disagreement exceeded agreement, indicating perceived structural or capacity-related constraints at the household level.

Table 1. Percentage of responses regarding willingness to participate, economic expectations, and basic infrastructure conditions in Tsuntsuntsa.

Item	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
The household has the potential to participate	4.13	50.41	4.13	33.06	8.26
Agritourism could generate benefits	0.00	0.00	8.26	50.41	41.32
The household is prepared to host tourists	16.53	16.53	4.13	50.41	12.40
Agritourism is viable for the community	4.13	0.00	12.40	28.93	54.55

These findings reveal a clear distinction between collective optimism and individual preparedness. The community broadly recognizes agritourism as economically beneficial and socially viable; however, many households express uncertainty regarding their own capacity to participate (Table 1). This heterogeneity provides an empirical foundation for the subsequent optimization model, which explicitly accounts for differences in predisposition and hosting capacity across households.

The four perception indicators demonstrated excellent internal consistency (Cronbach's $\alpha = 0.91$), supporting their aggregation into a composite Agritourism Feasibility Index. The index presented a mean of 3.67 (SD = 0.71), with observed values ranging from 1.75 to 4.75. The results suggest that agritourism development in Tsuntsuntsa should follow a phased, capacity-building approach, prioritizing the initial inclusion of better-prepared households.

Current state of agritourism and its socioeconomic viability

Table 2 presents community perceptions across four dimensions: familiarity with agritourism, perceived impact, sustainability of current practices, and adequacy of local implementation. The results show a consistent pattern of optimism about agritourism's potential, coupled with recognition of operational and organizational constraints.

Familiarity with the concept remains moderate to low, indicating limited technical understanding of the requirements and operational dynamics of agritourism. Despite this limitation, perceptions of potential impact are predominantly positive, with most respondents rating agritourism as having medium to high socioeconomic benefits. Perceptions of the sustainability of current agricultural practices are largely favorable, indicating that agritourism could be integrated without major structural changes to existing production systems. In contrast, assessments of local readiness for implementation are more cautious, reflecting concerns regarding governance capacity, infrastructure, coordination, and institutional support.

Table 2. Perceptions of agritourism in the Tsuntsuntsa community.

Indicator	Low (1–2)	Medium (3)	High (4–5)
Familiarity with the concept	35%	25%	40%
Perceived global impact	20%	30%	50%
Sustainability of current practices	25%	25%	50%

Adequate local implementation	40%	30%	30%

Modeling the impacts of agritourism

Table 3 outlines four scenarios assessed through the optimization model. An increase in the budget from 800 to 1,200 resulted in the inclusion of two additional families, raising the total from 8 to 10 and increasing total benefits from 14,000 to 16,950 units. The Gini index rose marginally from 0.27 to 0.30. Adjustments to minimum capacity thresholds had a minimal impact on household selection under lower-budget scenarios. These findings indicate that budget size is the primary determinant of program expansion, while distributive inequality remained within a low-to-moderate range.

Table 3. Quantification of variables for optimization scenarios.

Scenario	Budget	Min. Capacity	Selected Households	Total Benefit	Gini Index
Base	800	30	8	14,000	0.27
Higher Budget	1,200	30	10	16,950	0.30
Higher Capacity	800	40	8	14,000	0.27
Both Increased	1,200	40	10	16,950	0.30

Interactive agritourism pilot model for the Tsuntsuntsa community

Figure 4 presents the proposed pilot model for interactive agritourism in the Tsuntsuntsa community. This model integrates quantitative outputs from the optimization model with qualitative insights obtained through participatory diagnosis. The diagram encompasses essential structural, organizational, and operational components organized into four interconnected modules: (i) community governance, (ii) household selection and readiness, (iii) visitor experience design, and (iv) support services and enabling conditions.

The governance module establishes the model's foundational institutional framework, emphasizing the creation of a community agritourism committee responsible for coordination, benefit-sharing agreements, and decision-making. The household selection module translates the optimization model's results into practical criteria for selecting host families, incorporating an equity dimension by explicitly considering Gini-based scenarios. The visitor experience module outlines core activities including agricultural demonstrations (coffee, cacao, fish farming), cultural practices, traditional gastronomy, and guided ecological walks. The support services module encompasses essential infrastructure, training programs, marketing strategies, and partnerships necessary for successful implementation.

Table 4 summarizes the essential operational guidelines for implementing the interactive agritourism pilot program, organized around three key components: infrastructure, training, and governance/inclusion.

Table 4. Guidelines for the interactive agritourism pilot program.

Component	Description
Infrastructure	Development of essential facilities, including enhanced sanitation systems, safe accommodations for visitors, a communal kitchen for culinary activities, and designated areas for cultural and agricultural demonstrations.
Training and Capacity Building	Ongoing training programs in hospitality, tour guiding, cultural interpretation, food safety, and basic entrepreneurship. Enhancing soft skills such as communication, customer service, and the management of visitor expectations.
Governance, Inclusion, and Community Organization	Formation of a community agritourism committee tasked with coordination, decision-making, visitor management, and transparent benefit-sharing. Establishment of internal regulations to ensure equity, rotation mechanisms, and clearly defined host responsibilities.

Discussion

Households with the potential to engage in interactive agritourism

The results indicate a clear distinction between the community's collective optimism about agritourism and households' individual readiness to participate (Peroff et al., 2022; Khamung, 2015). While most respondents view agritourism as beneficial and viable, fewer believe their own families are adequately prepared (Tew & Barbieri, 2012). This discrepancy reflects a typical pattern documented in studies of indigenous and rural tourism, in which communities express strong social acceptance but face capacity constraints at the household level (Fournis & Fortin, 2017). In Tsuntsuntsa, the gaps identified—particularly regarding infrastructure, hosting readiness, and understanding of agritourism—align with findings from Amazonian and Andean contexts (Granit, 2023).

Nevertheless, the community's high expectations for economic improvement suggest that agritourism aligns with their development priorities. Research indicates that perceived benefits are a key predictor of long-term community commitment and collective action in tourism ventures (Hwang & Stewart, 2017). The optimization model addresses this challenge by quantifying differences at the household level, enabling a fair and evidence-based selection process (Bwana et al., 2015). Overall, the findings demonstrate that while enthusiasm is widespread, structured capacity-building interventions are essential to prevent the concentration of benefits among a few already-prepared households—an issue frequently reported in indigenous ecotourism initiatives (Sjölund et al., 2025; Chen et al., 2025).

Current status of agritourism and its socioeconomic viability

The analysis of community perceptions reveals a general sense of desirability and feasibility, despite recognition of certain organizational limitations (Chassang et al., 2024). The community acknowledges the need for stronger governance mechanisms (Schilcher, 2007). Research on community-based tourism emphasizes that governance quality, transparency, and benefit-sharing agreements are critical factors for sustainability (Dangi & Jamal, 2016). The limited readiness observed underscores the need to strengthen local governance structures before implementing agritourism at scale. Nearly three-quarters of respondents view agricultural practices positively, providing a strong foundation for agroecological tourism that is gaining global attention due to rising demand for experiential and environmentally responsible activities (Han et al., 2016; Cavalleri et al., 2022).

Furthermore, the study's findings align with global trends indicating that agritourism can diversify income, boost resilience against climate and market shocks, and empower vulnerable groups—particularly indigenous and rural women (Nathalie et al., 2025). However, researchers caution that transitioning from subsistence agriculture to tourism requires specific training and ongoing institutional support (Qu et al., 2023). The strong perceived benefits among respondents reflect findings from South American agritourism case studies, which show that even small-scale pilot initiatives can lead to significant improvements in household well-being (Mele & Del Vecchio, 2025).

Modeling the impacts of agritourism

The optimization model offers a robust and innovative approach to balancing economic efficiency and equity in benefit distribution. The scenarios indicate that increased budgets lead to greater household participation and broader community benefits, with a slight increase in income inequality as indicated by the Gini values (Sangnak, 2025). This finding aligns with global research showing that tourism growth often raises overall income while posing risks of unequal benefit distribution (Sacchi & Salotti, 2014).

The Gini indices observed (ranging from 0.27 to 0.30) fall within the internationally recognized category of 'low to moderate' inequality (Dietz et al., 2025; Poirier et al., 2020). By integrating the Gini index as a secondary objective, the model serves as a practical tool for decision-makers to visualize the impacts of various implementation strategies, reflecting recent advancements in multi-objective optimization for rural development (Skuras et al., 2006). The Pareto frontier and Lorenz curve results illustrate the trade-offs between efficiency and equity inherent in community tourism. Similar patterns have been observed in indigenous contexts in Brazil, Nepal, and Southeast Asia, where tourism expansion boosts revenues but necessitates strong governance mechanisms (Dangi & Petrick, 2021).

The modeling outcomes support the rationale for a phased household inclusion strategy, where initial investments prioritize better-prepared families, followed by structured capacity-building activities. This approach aligns with best practices recommended by recent agritourism and ecotourism frameworks that emphasize inclusivity, progressive integration, and adaptive governance (Addinsall et al., 2017). In summary, the model confirms that interactive agritourism can provide meaningful socioeconomic benefits in Tsuntsuntsa (Baipai et al., 2023), while avoiding the pitfalls of inequitable tourism development, provided that transparent governance and targeted interventions accompany the operational roll-out.

Limitations

This study has several limitations. First, income projections in the optimization model rely on estimated predisposition and hosting capacity variables rather than observed tourism revenues, so projected benefits show potential—not realized—economic outcomes. Second, the modeled scenarios assume stable demand and do not consider market volatility, seasonal fluctuations, or external shocks. Future research should incorporate demand-side modeling and sensitivity analysis to improve predictive accuracy. Third, while the

census-based design (n = 121) reduces sampling error within the community, the findings are applicable only to this specific context and should be interpreted with caution before generalizing elsewhere. Finally, the study measures perceived feasibility rather than long-term outcomes; future research should monitor the implementation period to determine whether the projected equity–efficiency balance is realized.

Conclusions

The results reveal strong collective support for agritourism alongside heterogeneous household readiness, underscoring the need for phased implementation and targeted capacity-building strategies. The incorporation of the Gini coefficient into the optimization model shows that increasing total community benefits can be achieved while maintaining low to moderate levels of inequality, highlighting that efficiency and equity can be jointly addressed through appropriate planning tools.

The proposed pilot model translates these findings into a practical and scalable roadmap integrating governance mechanisms, transparent household selection, culturally grounded visitor experiences, and enabling support services. Overall, interactive agritourism emerges not only as an economic alternative but as a development pathway that strengthens community governance, promotes equitable benefit-sharing, and aligns with broader sustainability objectives in indigenous territories. The integration of multi-objective optimization with participatory planning demonstrates that equitable agritourism development in indigenous Amazonian communities is not only conceptually desirable but operationally feasible under structured governance and phased inclusion strategies.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Declaration of responsibility of authorship

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