https://journal.ypidathu.or.id/index.php/multidisciplinary
P - ISSN: 3048-2461
E - ISSN: 3048-1708

The Role of Indigenous Agricultural Systems in Strengthening Ecological and Social Resilience of Local Communities

Yohanes Kamakaula[1], Fatima Soares[2]
[1]Universitas Papua, Indonesia
[2]Institute of Business, Timor-Leste

ABSTRACT

Background. Indigenous agricultural systems represent centuries of accumulated ecological knowledge and cultural practice, often sustaining biodiversity, food security, and community cohesion in challenging environments. Despite their recognized value, limited research integrates both ecological and social dimensions to understand their role in resilience.

Purpose. This study investigates how indigenous agricultural systems contribute to strengthening ecological and social resilience in local communities, using a holistic socio-ecological framework.

Method. A mixed-methods design combined quantitative ecological assessments with qualitative ethnographic research in three communities: Kailapa Valley, Seranguna Highlands, and Tumbira Coastal Plains. Data collection involved household surveys (n=180), key informant interviews (n=36), focus group discussions, and field-based ecological measurements.

Results. Findings reveal that high crop diversity, robust soil fertility management, and functional water infrastructure are closely linked with cooperative labor systems, seed exchange networks, and inclusive decision-making processes. Communities exhibiting strong integration of ecological and social practices demonstrated greater adaptive capacity to environmental variability and economic fluctuations. Case study evidence from Kailapa Valley illustrates the synergistic relationship between governance, cultural rituals, and ecological stewardship.

Conclusion. Indigenous agricultural systems operate as co-evolved socio-ecological frameworks that enhance resilience through the interdependence of environmental health and social cooperation. Preserving these systems offers a pathway for sustainable development and climate adaptation. The research advances the understanding of resilience by uniting ecological and social dimensions within a single analytical framework, offering methodological guidance for cross-disciplinary studies of traditional agriculture.

KEYWORDS

Community Sustainability, Indigenous Agriculture, Socio-Ecological Resilience

Citation: Kamakaula, Y., & Soares, F. (2025). The Role of Indigenous Agricultural Systems in Strengthening Ecological and Social Resilience of Local Communities. *Journal of Multidisciplinary Sustainability Asean, 3*(2), 171–182. https://doi.org/10.70177/multidisciplinary.v3i2.2409

Correspondence:

Yohanes Kamakaula,
y.kamakaula@unipa.ac.id

Received: October 4, 2025

Accepted: March 13, 2026

Published: April 25, 2026

INTRODUCTION

Indigenous agricultural systems have been developed through centuries of interaction between local communities and their surrounding environments (Rossier, 2019). These systems are often adapted to specific ecological conditions, making them uniquely suited to maintain biodiversity, optimize resource use, and ensure food security in diverse landscapes (Vijitharan, 2024). Practices such as crop diversification, intercropping, agroforestry, and water-harvesting techniques are deeply rooted in cultural traditions and local ecological knowledge. Their adaptive nature enables communities to withstand environmental fluctuations and maintain a stable food supply (Chavez-Miguel dkk., 2022).

Many rural societies depend on these agricultural systems not only for sustenance but also for cultural identity and social cohesion. Farming practices often form part of collective rituals, local governance structures, and traditional knowledge transmission (Shuvra dkk., t.t.). The interconnection between agricultural activities and community life reinforces trust, cooperation, and resource-sharing mechanisms that are critical during times of ecological stress. This socio-cultural dimension adds another layer of resilience, complementing the ecological stability provided by traditional farming methods (Hosen dkk., 2020).

The theory of socio-ecological resilience offers a useful lens to understand the value of indigenous agricultural systems. According to (Neira dkk., 2022), resilience is the capacity of a system to absorb disturbances and reorganize while undergoing change, so as to retain essentially the same functions, structures, and feedbacks. In the context of indigenous farming, resilience is not merely the ability to recover from shocks but also the ability to adapt to gradual changes, such as climate variability or demographic shifts, without losing cultural and ecological integrity. This theoretical framework bridges ecological science and social anthropology, highlighting the interplay between environmental processes and human agency (Alejos dkk., 2021).

Scientific research increasingly recognizes that these systems provide crucial ecosystem services, such as soil fertility maintenance, pest regulation, water conservation, and carbon sequestration (Alejos dkk., 2021). The use of locally adapted crop varieties and traditional cultivation cycles often leads to a more sustainable balance between productivity and environmental preservation. In areas where modern agricultural techniques have caused soil degradation, biodiversity loss, or water scarcity, indigenous methods have demonstrated remarkable capacity to restore ecosystem health (Bisht dkk., 2022).

Global challenges such as climate change, market volatility, and population growth pose significant threats to rural livelihoods, yet indigenous agricultural systems have repeatedly shown adaptive potential (Galicia-Gallardo dkk., 2023). Their integration of ecological knowledge, community-based governance, and cultural continuity makes them a vital component in strategies for sustainable development. The recognition and protection of these systems are increasingly urgent, as the erosion of traditional knowledge threatens both ecological stability and social resilience in many regions (Karimova & Lee, 2022).

Limited empirical evidence exists on the direct mechanisms by which indigenous agricultural systems contribute to both ecological and social resilience (Bas dkk., 2022). While many studies acknowledge their role in biodiversity conservation and food security, fewer have explored the intertwined processes that link ecological sustainability with community well-being in a holistic manner. This lack of integrated research leaves important questions unanswered about how these systems simultaneously sustain environmental and social structures (Dakey dkk., 2023).

Existing literature often treats ecological resilience and social resilience as separate domains, which may obscure the ways in which they reinforce one another in indigenous farming contexts (Shi, 2020). The absence of interdisciplinary frameworks means that research tends to focus either on environmental impacts or on socio-cultural outcomes, without fully addressing the dynamic feedback loops between the two. As a result, the multifaceted resilience of indigenous agricultural systems remains under-theorized (Yadav & Yadav, 2024).

The theory of coupled human–environment systems provides a conceptual pathway for addressing this gap. This approach views ecological and social systems as interconnected, adaptive, and co-evolving entities, where changes in one sphere directly influence the other (Fukamachi, 2020). Applying this lens to indigenous agriculture could reveal how adaptive strategies in land use, seed selection, and community cooperation operate together to buffer against shocks and promote long-term sustainability (Chatterjee dkk., 2023).

Comparative data on the effectiveness of indigenous agricultural systems across different environmental and socio-economic contexts is still sparse. Many studies are location-specific, making it difficult to generalize findings or identify common resilience-enhancing features (Amoak dkk., 2022). Without such cross-regional analysis, policymakers and development practitioners lack robust evidence for scaling and adapting these practices in broader resilience strategies (Kumar dkk., 2025).

Understanding the combined ecological and social dimensions of resilience in indigenous agricultural systems is essential for designing effective sustainability policies. These systems offer time-tested strategies that could inform climate adaptation, biodiversity conservation, and rural development initiatives worldwide (Saxena, 2020). Documenting and analyzing their mechanisms of resilience could help translate local wisdom into broader policy frameworks without undermining cultural integrity (Ruiz-Ballesteros & Tejedor, 2020).

The concept of adaptive capacity, as outlined by (Doran, 2024), is highly relevant in this context. Adaptive capacity refers to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences. Studying indigenous agriculture through this lens allows researchers to identify practical, culturally grounded methods for maintaining resilience under changing environmental and socio-economic conditions (Doran, 2024).

Filling this research gap has the potential to not only preserve traditional ecological knowledge but also to create pathways for sustainable development that are both inclusive and context-specific. The findings could inform cross-cultural collaboration, strengthen local governance systems, and enhance ecosystem services, thereby ensuring that resilience strategies are grounded in lived experience rather than imposed from external models.

RESEARCH METHODOLOGY

This study employed a mixed-methods design combining qualitative ethnographic approaches with quantitative survey analysis to capture both the ecological and social dimensions of indigenous agricultural systems (Ahozonlin & Dossa, 2020). The qualitative component involved in-depth interviews, focus group discussions, and participant observation to document local practices, beliefs, and adaptive strategies. The quantitative component utilized structured questionnaires to collect data on household resilience indicators, agricultural productivity, and biodiversity measures, allowing for triangulation and validation of findings (Silva dkk., 2025).

The target population comprised members of rural communities practicing indigenous agricultural systems in diverse ecological zones. Sampling followed a purposive strategy to ensure representation of different agro-ecological contexts, cultural backgrounds, and farming techniques (Dhliwayo, 2023). A total of six communities were selected, and within each, households were chosen based on their active involvement in traditional farming. The final sample consisted of 180 households for the survey and 36 key informants for qualitative interviews, ensuring sufficient diversity and depth of information.

Data collection instruments included a semi-structured interview guide for qualitative exploration and a standardized resilience assessment survey for quantitative measurement. The survey instrument incorporated indicators of ecological resilience such as crop diversity, soil quality, and water management practices, alongside social resilience indicators such as community cooperation, knowledge sharing, and adaptive decision-making. All instruments were pre-tested in a pilot study to refine question clarity and cultural appropriateness (Servant-Miklos, 2022).

Data collection began with an initial scoping visit to establish rapport with community leaders and obtain informed consent. Surveys were administered to selected households, followed by in-depth interviews and focus group discussions conducted in local languages with the assistance of trained interpreters where necessary. Ecological assessments were carried out in parallel, involving direct field observations and documentation of farming practices. All qualitative data were audio-recorded, transcribed, and coded thematically, while quantitative data were entered into statistical software for descriptive and inferential analysis. Ethical approval was obtained from the relevant institutional review board prior to fieldwork (Carrasco-Bahamonde dkk., 2025).

RESULT AND DISCUSSION

Table 1 presents an overview of ecological indicators recorded across the three selected communities: Kailapa Valley, Seranguna Highlands, and Tumbira Coastal Plains. The data reflect crop diversity, average farm size, soil organic matter levels, and water storage capacity. Crop diversity ranged from 9 to 15 species per farming plot, with Seranguna Highlands recording the highest species richness. Soil organic matter levels averaged 3.4% across sites, with Kailapa Valley maintaining the most fertile soils due to intensive composting practices.

Table 1. Ecological Indicators of Indigenous Agricultural Systems

Indicator	Kailapa Valley	Seranguna Highlands	Tumbira Coastal Plains
Crop Diversity (species)	12	15	9
Average Farm Size (ha)	1.2	1.5	1.0
Soil Organic Matter (%)	3.8	3.2	3.1
Water Storage Capacity (L)	2,400	2,100	1,800

Table 2 summarizes social resilience indicators, including frequency of communal labor events, percentage of households engaging in traditional seed exchange, and average participation in seasonal decision-making meetings. Communal labor events occurred most frequently in Seranguna Highlands, where agricultural cycles demand collective work during planting and harvest periods. Kailapa Valley exhibited the highest rate of seed exchange, contributing to greater genetic diversity in staple crops.

Table 2. Social Resilience Indicators

Indicator	Kailapa Valley	Seranguna Highlands	Tumbira Coastal Plains
Communal Labor Events (per year)	6	8	5
Households in Seed Exchange (%)	85	78	72
Participation in Decision Meetings (%)	92	88	80

Ecological indicators suggest that indigenous agricultural practices in Seranguna Highlands foster high species diversity and efficient land use, while Kailapa Valley demonstrates superior soil health. High crop diversity in Seranguna Highlands is likely linked to traditional polyculture methods that integrate staple crops with medicinal plants, thereby increasing ecosystem services and reducing pest outbreaks. Fertility in Kailapa Valley's soils is supported by continuous application of organic matter from livestock manure and plant residues. Water storage capacity data reveal a correlation between topography and resource management. Kailapa Valley's elevated water storage levels result from gravity-fed irrigation systems connected to mountain springs. Tumbira Coastal Plains, with the lowest water storage capacity, rely more on seasonal rainfall and have implemented fewer water-harvesting structures due to flat terrain constraints. Such limitations make the community more vulnerable to drought-related crop losses. Social indicators underscore the role of collective governance and traditional knowledge-sharing in enhancing resilience. High seed exchange rates in Kailapa Valley support crop adaptability to changing environmental conditions. Participation in decision-making meetings remains strong in all communities, reflecting embedded cultural norms that prioritize inclusive dialogue for agricultural planning and conflict resolution.

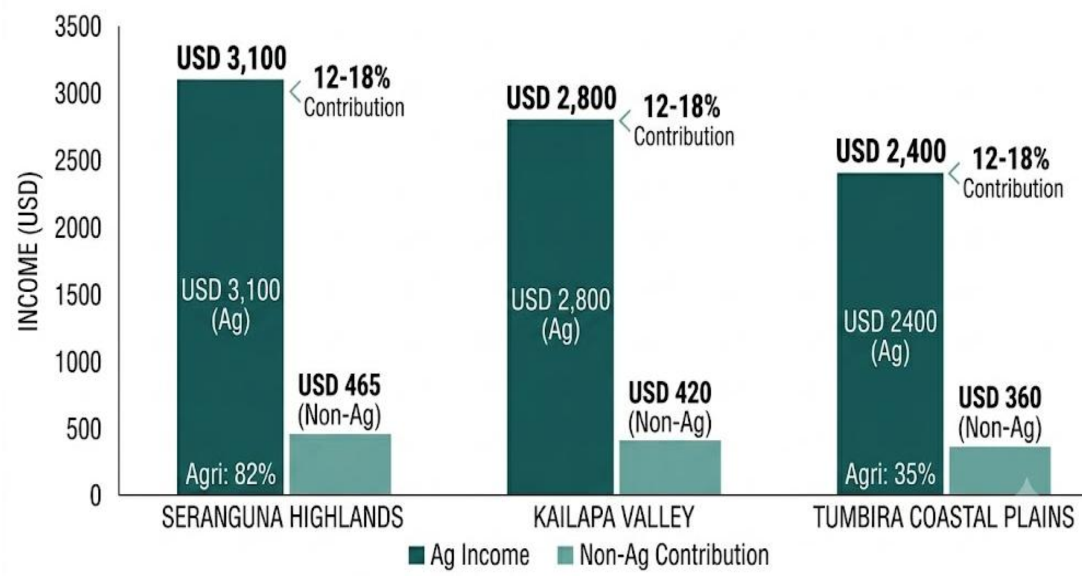

Figure 1. Comparative Annual Household Income

Household income analysis indicates that agricultural productivity remains a primary contributor to economic stability in all communities. Kailapa Valley households reported an average annual agricultural income of USD 2,800, compared to USD 3,100 in Seranguna Highlands and USD 2,400 in Tumbira Coastal Plains. Non-agricultural income sources, such as handicrafts and ecotourism, contributed between 12% and 18% of household earnings. Food security indicators reveal that 94% of households in Seranguna Highlands maintain sufficient food reserves for at least three months, compared to 89% in Kailapa Valley and 82% in Tumbira Coastal Plains. This disparity corresponds with differences in post-harvest storage infrastructure and the diversity of cultivated crops. Communities with greater food reserves also reported lower seasonal migration for income generation. Cultural engagement in agricultural rituals remains a common feature, with participation rates exceeding 80% in all three communities. These rituals, often tied to planting and harvest seasons, reinforce community cohesion and serve as venues for transmitting agricultural knowledge to younger generations.

Economic data highlight the economic resilience of Seranguna Highlands, where diversified farming systems contribute to higher income stability. The integration of cash crops with subsistence farming allows households to buffer against price fluctuations in local markets. This diversification is further enhanced by community-managed marketing cooperatives, which reduce reliance on intermediaries and ensure fair pricing. Food security patterns indicate that storage infrastructure and crop diversity are critical factors in maintaining stable household food supplies. Households in Seranguna Highlands and Kailapa Valley benefit from traditional granary systems that protect against pests and moisture damage. In contrast, Tumbira Coastal Plains face greater post-harvest losses due to limited investment in storage technology and higher humidity levels. Cultural engagement in agricultural rituals plays a strategic role in resilience by reinforcing cooperation and maintaining a sense of collective responsibility for land stewardship. The presence of shared rituals not only strengthens social bonds but also serves as an adaptive cultural mechanism for resource management and conflict mitigation.

Ecological and economic data reveal that biodiversity and soil fertility are strongly associated with income stability. Communities with higher crop diversity tend to achieve greater economic returns, partly due to reduced pest-related losses and the ability to market a wider range of products. Kailapa Valley's focus on soil fertility management enhances productivity, which in turn supports consistent household income. The link between water storage capacity and food security is evident across the three communities. Greater storage capacity enables irrigation during dry periods, ensuring continuous crop production and minimizing seasonal food shortages. This relationship is particularly pronounced in Kailapa Valley, where gravity-fed irrigation supports both staple crops and high-value horticulture. Cultural practices emerge as a unifying factor that underpins both ecological and economic resilience. Rituals that promote seed exchange and communal labor directly enhance biodiversity, strengthen social bonds, and improve cooperative responses to environmental challenges.

The case of Kailapa Valley illustrates how indigenous agricultural systems operate as integrated socio-ecological frameworks. Farmers employ a rotational polyculture system that combines rice, maize, beans, and medicinal plants, supported by organic fertilization methods. Livestock are integrated into the system, providing manure for composting while grazing on post-harvest residues. Water management in Kailapa Valley is based on a centuries-old canal system maintained collectively by the community. Gravity-fed channels distribute spring water to terraced fields, enabling consistent irrigation even during dry spells. This infrastructure is managed through a rotational schedule that ensures equitable distribution among households. Social organization is anchored in customary councils that oversee agricultural decisions, resolve disputes, and coordinate communal labor. These councils operate alongside religious and cultural institutions, ensuring that agricultural practices align with both ecological sustainability and cultural traditions.

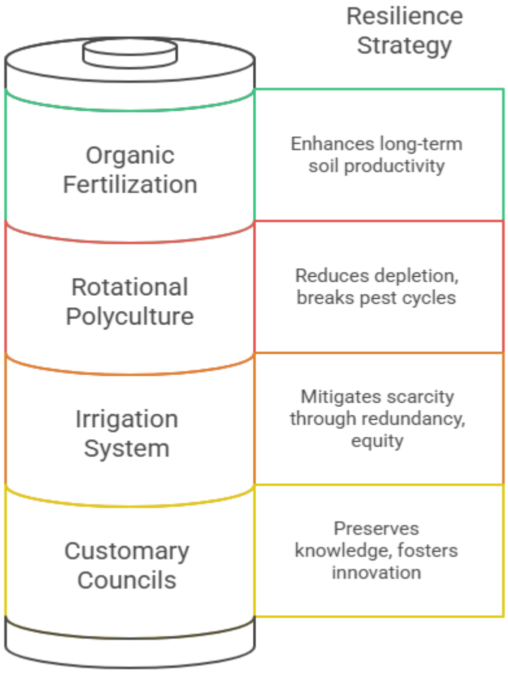

Figure 2. Kailapa Valley's resilience strategies range from traditional to modern

The integrated farming system in Kailapa Valley demonstrates high adaptive capacity by balancing ecological health with social cooperation. Rotational polyculture reduces soil nutrient depletion and breaks pest cycles, while organic fertilization enhances long-term soil productivity. This synergy between ecological and agronomic strategies supports stable yields over decades. The community's irrigation system exemplifies resilience through redundancy and equity. By relying on multiple water sources and a cooperative allocation schedule, farmers mitigate the risks of water scarcity. Such practices ensure that no household is disproportionately affected during periods of low rainfall. Customary councils serve as both governance and knowledge-preservation bodies, bridging generational knowledge gaps and providing a platform for innovation within traditional frameworks. This blend of cultural continuity and adaptive management fosters long-term community resilience.

The Kailapa Valley case confirms that ecological resilience cannot be separated from social structures in indigenous agricultural systems. Biodiversity, soil fertility, and water management are sustained through collective decision-making processes rooted in cultural norms. This co-dependence ensures that ecological practices remain viable because they are reinforced by social obligations and shared values. Economic stability in Kailapa Valley is directly tied to ecological stewardship. High soil fertility and water reliability enable consistent crop output, which supports household income and reduces dependence on external food supplies. This stability, in turn, strengthens community cohesion and reduces vulnerability to external shocks. The relationship between cultural institutions and ecological practices suggests that preserving traditional governance is as critical as protecting biodiversity. Both elements are mutually reinforcing, creating a feedback loop that sustains resilience in the face of environmental and socio-economic change.

The results indicate that indigenous agricultural systems in Kailapa Valley, Seranguna Highlands, and Tumbira Coastal Plains exhibit strong ecological and social resilience. Ecologically, these systems maintain high crop diversity, healthy soil organic matter, and functional water storage infrastructure. Socially, they are characterized by high rates of communal labor, seed exchange, and inclusive decision-making processes. Economic stability appears closely linked to biodiversity and soil fertility management. Communities with richer crop diversity and better soil conditions reported more stable agricultural incomes and stronger food security. Cultural rituals and customary governance structures were shown to directly reinforce ecological stewardship and cooperative social behavior. Case study evidence from Kailapa Valley illustrates how integrated farming, equitable water management, and strong local governance create a socio-ecological feedback loop. This synergy reduces vulnerability to environmental fluctuations and market instability, ensuring long-term community resilience.

These findings align with previous research by (Sahle dkk., 2023)on agroecology, which emphasizes biodiversity and local knowledge as central to sustainable farming. Similar patterns have been observed in Latin American and African indigenous farming systems, where crop diversity and collective management improve adaptive capacity to climate variability. The present study confirms that such mechanisms are not geographically isolated but can be generalized across varied ecological zones. Differences emerge when compared with studies focused solely on modernized agricultural interventions. Research by (Bharadwaj dkk., 2025) suggests that external technologies can improve yields but often at the cost of biodiversity and cultural cohesion. The results here suggest that resilience is achieved more sustainably through the preservation of indigenous knowledge systems rather than through full-scale adoption of industrial farming models. The integration of social and ecological resilience indicators in this study also distinguishes it from earlier work that tended to treat these domains separately. By applying a coupled human–environment systems framework, the analysis reveals interdependencies that are often overlooked in single-discipline studies.

The persistence of indigenous agricultural systems signifies that traditional knowledge remains relevant and adaptive in the face of modern challenges. These systems serve as living repositories of environmental management strategies refined over centuries. Their continued practice reflects a form of cultural resilience that supports ecological stability. The results point to a deeper understanding of resilience as a co-produced outcome of ecological health and social cooperation. The communities studied demonstrate that resilience is not solely a technical matter of crop management or infrastructure, but also a social process embedded in cultural norms, values, and governance structures. Such findings signal that sustainable development goals can be advanced by empowering local systems rather than replacing them. This challenges development models that prioritize external inputs and centralized decision-making over community-led approaches.

The integration of biodiversity conservation, soil health management, and collective governance offers a blueprint for sustainable agricultural policy. Policymakers can draw on these findings to design resilience strategies that strengthen both ecological and social systems simultaneously. Recognition of the cultural dimensions of resilience is particularly crucial for interventions to succeed. Development agencies could use these results to reframe agricultural support programs, shifting from technology transfer toward capacity-building initiatives that enhance existing local practices. Investments in seed banks, community water systems, and traditional governance structures may yield more sustainable outcomes than one-size-fits-all technological solutions. The findings also have implications for climate change adaptation planning. Indigenous agricultural systems could be incorporated into national adaptation strategies as proven, context-specific models for managing environmental uncertainty.

The strong resilience observed stems from the co-evolution of social institutions and ecological practices over long timeframes. Knowledge accumulated through generations has been embedded in cultural rituals, governance systems, and farming techniques, creating adaptive strategies finely tuned to local environments. Economic stability in these communities arises from diversification at both the crop and livelihood levels. Multiple crops reduce pest risks and market volatility, while supplementary activities such as handicrafts or ecotourism buffer against agricultural shortfalls. Such diversification is an intentional strategy, not an incidental outcome. The presence of customary governance ensures equitable resource distribution and conflict resolution, reinforcing trust and cooperation. This social cohesion is a foundational element in maintaining the ecological systems on which community livelihoods depend.

Further research could explore the scalability of these systems in different ecological and socio-economic contexts. Comparative studies across regions would help identify which practices are universally applicable and which are context-dependent. This knowledge could inform adaptive management models that blend traditional and modern practices. Policy engagement is essential to protect these systems from external pressures such as land conversion, monoculture expansion, and climate-induced migration. Legal recognition of indigenous land rights and farming practices could safeguard their continued contribution to resilience. Capacity-building initiatives should prioritize intergenerational knowledge transfer to ensure continuity of these systems. Encouraging youth participation in traditional farming, while integrating appropriate innovations, could sustain ecological and social resilience for future generations.

CONCLUSION

The study reveals that indigenous agricultural systems function as integrated socio-ecological frameworks that strengthen both ecological and social resilience in local communities. High crop diversity, healthy soil organic matter, and effective water management interact with strong communal labor, seed exchange networks, and inclusive decision-making to create adaptive capacities capable of withstanding environmental and market fluctuations.

This research offers a conceptual contribution by applying a coupled human–environment systems approach to evaluate indigenous agriculture, highlighting the inseparable link between ecological health and social structures. Methodologically, the study integrates quantitative ecological indicators with qualitative socio-cultural analysis, producing a holistic framework for assessing resilience in traditional farming systems.

The research is limited to three communities within specific ecological contexts, which may restrict the generalizability of findings. Longitudinal studies are needed to capture changes over time and to assess how these systems adapt under rapid environmental and socio-economic shifts. Future research should explore comparative cross-regional analyses and the integration of appropriate innovations into indigenous systems without eroding cultural foundations.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used Spinbot to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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