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Integrating traditional ecological knowledge and participatory planning in bamboo resource development: A case from indigenous communities in West Papua, Indonesia

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Abstract

Bamboo is a multifunctional plant with great potential to support sustainable livelihoods, especially in rural areas and indigenous communities. In West Papua, bamboo utilization is still traditional and has not been productively integrated into the local economy. This study analyzes bamboo's potential, perceptions, and community-based development strategies by combining social, economic, cultural, and ecological approaches. The method used is an exploratory mixed-methods approach, with data collection techniques including a quantitative survey of 27 respondents, in-depth interviews, participatory observation, and group discussion forums. Data were analyzed using descriptive statistics, qualitative thematic analysis, and integrative *joint display* techniques. The results indicate that bamboo is used mainly for construction, food, and traditional needs; however, its contribution to household income remains low (<25%) due to limited market access, production tools, and technical capacity. Most community members expressed support for bamboo conservation and high expectations for the government's role in training, institutional development, and product marketing. By integrating the Sustainable Livelihood Framework (SLF), Community-Based Natural Resource Management (CBNRM), and Political Ecology theoretical frameworks, this study concludes that bamboo development requires participatory strategies, local capacity building, and inclusive affirmative policies. Bamboo has the potential as an ecological and cultural commodity supporting sustainable development if managed collaboratively and contextually.

Keywords: Bamboo; Sustainable Livelihoods; Indigenous Communities; SLF; CBNRM; West Papua; Community-Based Strategies; Green Economy

1. Introduction

Bamboo is a biological resource with strategic ecological, economic, and cultural functions in tropical and subtropical regions. Globally, bamboo has been recognized as part of *nature-based solutions* supporting the Sustainable Development Goals (SDGs), particularly in reducing poverty, promoting a green economy, mitigating climate change, and conserving biodiversity (Zhou et al., 2022; INBAR, 2020). In addition to its ecological benefits, bamboo is also recognized as a rapidly renewable material with a low carbon footprint, making it highly potential for the global circular economy (FAO & INBAR, 2018).

In Asia, several countries have successfully developed the bamboo sector as an integral part of the rural economy and sustainable industry. In India, for example, bamboo-based agroforestry has proven effective in soil conservation and increasing smallholder farmers' incomes (Mishra et al., 2017). In the Philippines, community-based bamboo industry development approaches have been strengthened by national policies and research and innovation support, fostering

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a bamboo industry ecosystem (Soliven et al., 2024). In Vietnam and Laos, bamboo has become part of community-based rural development strategies and cultural landscape conservation (INBAR, 2020).

Despite Indonesia being known as one of the countries with the highest bamboo diversity (over 160 species), its economic utilization remains suboptimal. Several studies indicate that bamboo development in Indonesia remains subsistence-based and has not been integrated with modern markets, product innovation, or strong local institutions (Prasetyo et al., 2021; Pieter & Utomo, 2023). In Java and Bali, bamboo utilization has reached commercialization through the handicraft and architectural construction industries, but in Eastern Indonesia, particularly West Papua, the situation is vastly different.

Studies in Papua are still limited, but field reports and several local studies (Siregar et al., 2021) indicate that bamboo has significant value in the lives of indigenous communities, both as a material for houses, musical instruments, food (shoots), and symbols in traditional rituals. However, this utilization is still consumptive and has not been directed toward productive economic development. Unlike the regional context in Southeast Asia, which has moved towards community-based bamboo industry development, Papua does not yet have a specific strategy that positions bamboo as a strategic commodity, either in regional development planning or conservation policies.

Furthermore, few studies have integrated bamboo's ecological, economic, and cultural dimensions into a single community-based socio-ecological framework. This indicates a research gap, particularly in formulating bamboo development strategies that combine community-based natural resource management (CBNRM), sustainable livelihood frameworks (SLF), and grassroots innovation.

Based on this background, this study aims to formulate a community-based bamboo development strategy in West Papua through a participatory socio-ecological approach. The study focuses on: (1) indigenous communities' patterns of bamboo utilization, (2) perceptions of the economic, social, and ecological value of bamboo, (3) the potential of bamboo in tourism-based economic development and local culture, and (4) expectations regarding the role of the government and indigenous institutions. The novelty of this study lies in the integration of participatory approaches, cultural value-based resource management, and local action strategies derived from SWOT analysis and the integration of quantitative and qualitative data (joint display), which has rarely been done systematically, especially in the context of indigenous territories scattered across Papua.

2. Literature Review

2.1. Economic Value of Bamboo

Bamboo has significant economic potential as a primary raw material and a high-value-added commodity. Globally, the development of the bamboo industry in China, Ethiopia, and the Philippines demonstrates how bamboo can become a significant source of income through product diversification and value chain strengthening (INBAR, 2020; Abadega & Abawaji, 2020; Soliven et al., 2024). All bamboo parts—stems, leaves, and shoots—can be processed into household furniture, handicrafts, construction materials, textiles, and food.

However, in Indonesia, especially in West Papua, bamboo utilization is still traditional and has not been integrated into the local industrial framework. A study by Prasetyo et al. (2021) shows that the economic success of bamboo is highly dependent on access to training, capital, and markets. A survey by Pieter & Utomo (2023) reinforces that the micro-enterprise sector based on bamboo is vulnerable to failure without support from an institutional ecosystem and simple production technology.

2.2. Social Value and Community Empowerment

Bamboo also plays a vital role in social and economic empowerment. In the context of villages in Java and other marginal areas, skill training such as weaving and bamboo construction has proven to enhance community capacity, form independent business units, and create job opportunities (Anggita & Ilyas, 2024; Abdillah et al., 2023).

Community-based development approaches are considered effective in promoting inclusive socio-economic development. However, challenges arise when there is no integration of local institutions and access to microfinance that supports the sustainability of these businesses (Alamerew et al., 2024).

2.3. Cultural Values and Local Knowledge

Bamboo has rich cultural dimensions in many indigenous communities. Cheng et al.'s (2023) study of the Dulong community in Yunnan revealed that bamboo has symbolic value in religious rituals, traditional music, and local agricultural systems. Using bamboo in conventional house architecture, music, and farming tools in Indonesia has long been part of local wisdom (Soetjipto et al., 2019).

Unfortunately, the utilization of bamboo in West Papua has not been extensively studied regarding its cultural dimension. However, the relationship between indigenous communities in Papua and the forest and plants, including bamboo, is rich in spiritual and structural meaning. This study aims to fill this gap by exploring local communities' traditional ecological knowledge (TEK) as a basis for development strategies.

2.4. Ecological Value and Ecosystem Services

Ecologically, bamboo is known as a plant capable of supporting soil and water conservation. Its deep and extensive root system functions as a soil binder, water storage, and sediment and pollutant filter (Zhang & Jiang, 2019; Mishra et al., 2017). Bamboo's ability to absorb carbon twice as fast as ordinary trees makes it an essential tool in climate change mitigation (Zhou et al., 2022).

Bamboo also supports nature-based conservation strategies and aids in rehabilitating critical lands and watershed management. This potential is highly relevant to West Papua, which risks significant ecological degradation.

2.5. Contributions to Sustainable Development Goals (SDGs)

The utilization of bamboo supports the achievement of various SDG indicators, such as:

- SDG 1: Poverty eradication through local economic empowerment
- SDG 8: Decent work through the bamboo creative industry
- SDG 13 & 15: Climate action and preservation of terrestrial ecosystems

FAO & INBAR (2018) emphasize that bamboo sector development must be inclusive and cross-sectoral, involving governments, indigenous communities, and businesses. However, without supportive regulations, economic incentives, and an approach based on the rights of indigenous communities (FPIC – Free, Prior, and Informed Consent), this potential could lead to development biases that overlook social justice (UNDRIP, 2007).

2.6. Theoretical Foundation: Conceptual Framework

To understand and design holistic bamboo development strategies, this study uses the Community-Based Natural Resource Management (CBNRM) framework, which emphasizes local communities' collective management of natural resources (Berkes, 2004). This is combined with the Sustainable Livelihood Framework (SLF) to analyze the extent to which bamboo contributes to the sustainable livelihoods of local households. Additionally, a Political Ecology approach is employed to analyze power dynamics between indigenous communities, local governments, and the market sector in bamboo management, as well as to identify potential conflicts or marginalization, thereby revealing the holistic socio-ecological dynamics of bamboo utilization by indigenous communities.

First, the Sustainable Livelihood Framework (SLF) is used to analyze how bamboo contributes to the sustainability of household livelihoods. The SLF views people's livelihoods as determined by financial assets and five key capitals: natural, human, social, physical, and economic (DFID, 1999). In this context, bamboo acts as *natural capital* that can be optimized to strengthen *livelihood outcomes* such as increased income, food security, and fulfillment of cultural needs. However, access to other forms of capital, such as training (human capital), cooperatives (social capital), and production tools (physical capital), determines the extent to which communities can optimally utilize bamboo.

Second, Community-Based Natural Resource Management (CBNRM) theory highlights local communities' role as key actors in the sustainable management of natural resources. CBNRM emphasizes that the effectiveness of conservation and resource management will increase if the community incorporates local wisdom, traditional institutions, and direct economic incentives (Berkes, 2004; Fabricius & Koch, 2004). In this context, conventional bamboo forests and conservation practices are essential assets that can be strengthened through local institutions such as traditional bamboo cooperatives.

Third, a political ecology approach analyzes the power dynamics and social structures influencing how bamboo is perceived, accessed, and managed. Political ecology views resource management as inseparable from power relations

between local communities, the state, and the market (Robbins, 2012). In the case of West Papua, limited market access, dependence on external aid, and the lack of affirmative policies toward indigenous communities reflect the existence of structural inequalities that need to be addressed institutionally. This approach reinforces the understanding that development cannot be purely technocratic but must address issues of justice and local representation.

By combining these three approaches, the research can produce a descriptive, empirical, and conceptual-critical understanding, integrating economic, socio-, ecological, and political aspects into a holistic framework. This approach supports the formulation of community-based, culturally sensitive, and long-term sustainable bamboo development strategies.

3. Research Methodology

3.1. Research Approach and Design

This study employs a mixed-method approach with an exploratory-sequential model, prioritizing qualitative community-based exploration to understand the meanings, practices, and expectations regarding bamboo, followed by descriptive quantitative data to support generalization and the mapping of general patterns.

The conceptual framework of the research combines:

- Community-Based Natural Resource Management (CBNRM) – to describe the collective practices and cultural values of bamboo
- Sustainable Livelihood Framework (SLF) – to assess bamboo's contribution to household livelihoods
- Political Ecology – to examine the interactions between social actors, institutions, and control over bamboo resources

3.2. Research Location and Time

The research was conducted in Miyah District, Tambrauw Regency, West Papua, an area with an active indigenous community that utilizes bamboo daily. This location was selected purposefully based on the existence of bamboo utilization traditions and field accessibility. The research was conducted over one month.

3.3. Population and Sampling Technique

The research population comprises all households in the study area that utilize bamboo in economic, social, or cultural activities. The sample was selected using purposive sampling, with 27 primary respondents chosen based on their experience and involvement in bamboo utilization practices. Additional samples (key informants): Traditional leaders and village heads; Bamboo artisans; Community youth; Village government representatives

3.4. Data Collection Techniques and Instruments

This study employs several data collection techniques:

Table 1 Data Collection Techniques and Instruments

Technique	Purpose
Questionnaire	To collect quantitative data such as harvest frequency, number of stems, selling price, and income
Semi-structured interviews	To deepen understanding of perceptions, expectations, cultural practices, and barriers
Participatory observation	Recording direct activities related to bamboo utilization
Visual & local documentation	Identifying local bamboo species and their various uses

3.5. Operationalization of Research Variables

Table 2 Operationalization of Research Variables

Conceptual Aspects	Research Variables	Indicators	Measurement Scale	Data Sources / Techniques
Economics	Economic value of bamboo	Selling price per stem, volume crop per year, contribution to income	Ratio	Questionnaires, interviews
	Bamboo product diversification	Types of derivative products (woven goods, furniture, musical instruments, etc.)	Nominal	Observation, interviews
Social	Community empowerment	Access to training, participation in bamboo business groups	Ordinal	Interviews, documentation of local institutions
	Perceptions of bamboo as an economic opportunity	Level of community confidence in the economic potential of bamboo	Likert scale (1–5)	Questionnaires, FGD
Culture / Cultural	The symbolic meaning of bamboo in traditional life	Use of bamboo in rituals, music, and traditional buildings	Nominal	Interviews with traditional leaders, qualitative observation
	Local knowledge about types of bamboo	Number of bamboo species known and utilized by the community	Ratio	Local documentation and in-depth interviews
Ecological	Ecological value of bamboo	Perceptions of bamboo in soil and water conservation	Likert scale (1–5)	Questionnaires, FGD
	Bamboo conservation practices	Sustainable harvesting systems, reforestation	Nominal / Narrative	Direct observation, interviews
Institutional / External Support	Role of local government	Level of expectations and perceptions regarding government involvement	Likert scale (1–5)	Questionnaires, interviews
	Access to assistance and production tools	Ownership of tools, technical support, and capital assistance	Nominal	Interviews, documentation

3.6. Data Analysis

3.6.1. Quantitative Analysis

Quantitative data is analyzed using descriptive statistics (frequency, percentage) and presented in tables and diagrams. The analysis is conducted to identify:

- Distribution of respondent characteristics,
- Patterns of bamboo utilization,
- The economic contribution of bamboo,
- Public perceptions and expectations.

3.6.2. Qualitative Analysis

Qualitative analysis was conducted through five stages:

- Familiarization with transcript data.
- Initial coding of meaningful quotes.
- Categorization of codes into central themes.
- Interpretation and triangulation of narratives with quantitative data.
- Development of contextual thematic narratives.

3.6.3. Integrative Analysis (Joint Display)

The joint display matrix technique (Creswell & Plano Clark, 2018) combined quantitative and qualitative findings, allowing direct comparison between numerical results and field narratives to produce more comprehensive and valid insights.

3.6.4. SWOT and TOWS Analysis

A participatory SWOT analysis was conducted based on group discussions and in-depth interviews to formulate development strategies. Each SWOT factor was weighted and scored, then organized into a TOWS matrix to generate concrete strategies (SO, WO, ST, WT) appropriate to local conditions.

3.7. Research Ethics

This research adheres to the principles of social research ethics, including:

- Informed Consent: All respondents and key informants were provided with an explanation of the purpose, benefits, and their rights to participate before data collection.
- Confidentiality: Personal identity data is stored anonymously and used solely for scientific purposes.
- Cultural Context: The data collection process uses a cultural approach that respects local norms, customs, and authorities.

4. Results

4.1. Socio-Economic Characteristics of Respondents

Most respondents (70.4%) were male, with a dominant age group above 50 (54.2%). Most were farmers (60.7%) and had more than five family members (48.1%). This indicates that the respondents were experienced heads of households involved in subsistence-based natural resource use.

This characteristic supports the Sustainable Livelihood Framework (SLF) assumption that rural households depend highly on local resources to meet basic needs and maintain economic resilience.

4.2. Bamboo Utilization Patterns

85.2% of respondents use bamboo in their daily lives, primarily for: Construction (32.7%); Food (shoots) (30.6%); Household tools (18.4%); Artistic tools & traditional medicine (10.2%) The types of bamboo known and used reflect the richness of local knowledge, such as Bajarek, Kebwar, Ibwar, and Iririw.

Bamboo serves as an essential element in the socio-ecological system of the community. The diversity of species and uses indicates that bamboo is economically valuable and holds symbolic and cultural value, consistent with the findings of Cheng et al. (2023) on bamboo as part of *traditional ecological knowledge*.

4.3. Contribution to Household Income

The potential for household income from bamboo is reasonably available, but 59.3% of respondents do not sell bamboo, while those who sell it receive less than Rp5,000 per stalk. Additionally, 74% stated that bamboo does not contribute to their income. Furthermore, the value of bamboo products is low, as only four people make woven items, and one person engages in handicrafts.

The economic potential of bamboo remains latent and has not been fully capitalized. Significant constraints include: lack of market access, insufficient technical training, and low value addition of products. This reinforces previous studies by Pieter & Utomo (2023) that the micro bamboo sector is vulnerable to failure without support from an industrial ecosystem and affirmative regulations.

4.4. Cultural Value and Ecotourism Potential

Culturally, bamboo is used in traditional house architecture, religious rituals, traditional musical instruments, and village fences. Although not quantified statistically, these findings highlight the substantial symbolic value of bamboo in the lives of indigenous communities. This reaffirms bamboo's position not only as a natural resource but also as a cultural heritage.

From this, a strategic opportunity arises to develop bamboo tourism villages using an *eco-cultural tourism* approach, where bamboo is both the object and subject of conservation and education. This concept aligns with the values of *political ecology*, where natural resources are viewed within the context of social relations, power, and cultural identity.

4.5. Expectations toward the Government and Community Readiness

96.3% of respondents expressed hope for government support through training, production tools, or the establishment of bamboo cooperatives. This data is reinforced by qualitative findings that state: "We are ready to form a group if there are tools and training," and "We need the government to help open up access to markets."

This indicates the presence of social capital and community readiness to participate, which are essential as the foundation for community-based development. If designed in a participatory manner, the bamboo development approach will boost the local economy and strengthen indigenous communities' social and cultural structure.

4.6. Perceptions of Conservation and Expectations of the Government

100% of respondents support bamboo conservation, 96.3% hope for active government involvement, while 63% strongly agree that sustainable management improves well-being.

This indicates strong potential for building a collaborative conservation model, where communities are not only users but also guardians of the ecosystem. This aligns with the principles of CBNRM, which places local communities as the primary actors in resource management.

4.7. Integrative Analysis (Mixed-Data Integration – Joint Display)

Based on this integrative approach, quantitative data reinforces the dominant perception, while qualitative narratives deepen the social and cultural context. Furthermore, data integration shows that bamboo has significant economic and artistic potential, but its realization depends on technical, institutional, and market facilitation interventions, as detailed in the following table:

Table 3 Community Responses to Research Questions

Research Questions	Quantitative Findings	Qualitative Findings	Interpretation
How does bamboo contribute to household income?	74% of respondents stated that the contribution was <25%	"Do not know how to process it into products."	Bamboo has not become an economic commodity due to limited technical capacity, added value, and market access.
What are the community's expectations regarding the government's role in bamboo development?	96.3% hope for support	"We want training, tools, and bamboo cooperatives."	The government is key in driving bamboo economic transformation through technical and institutional facilitation.
What is the role of bamboo in the local culture of indigenous communities?	Not measurable quantitatively	"Used for traditional houses, rituals, music, and village fences."	Bamboo has high symbolic and spiritual value, making it highly potential to be developed as a basis for ecotourism and cultural narratives.
What are the main obstacles to the economic utilization of bamboo?	81.5% do not have derivative products	"We do not have the tools and do not know how to make products that sell."	Limited tools, skills, and product innovation are the main obstacles to increasing the economic value of bamboo.
How prepared is the community to manage bamboo-based businesses?	No explicit data available	"If training programs and tools exist, we can collaborate in groups."	The community is enthusiastic and ready to participate in community-based bamboo business development.

Source: In-depth interviews

Several strategic expectations emerged through interviews and focus group discussions: Technical training in bamboo product manufacturing (weaving, furniture); Formation of traditional bamboo cooperatives; Development of bamboo-

based cultural tourism villages; Mapping and protection of conventional bamboo forests; Local digital markets for bamboo crafts. These strategies indicate the community's readiness to transition from a consumer-oriented to a productive mindset, and they provide incentive systems, training, and institutional strengthening to support them. This supports the *novelty* of this research as a community-based study that systematically outlines grassroots initiatives.

Analysis results indicate that the potential development of bamboo faces various structural and social challenges. Despite significant opportunities through tourism markets and digital platforms, limited market access remains the primary constraint. The absence of specific policies is also a barrier, but this opens space for affirmative regulations rooted in local wisdom and customs. Limited training and production tools further hinder innovation, despite the community's high enthusiasm for bamboo product development. Fragmentation among institutions is also challenging, but this can be addressed by forming traditional cooperatives and collaboration between NGOs and local government agencies. Additionally, the low interest of the younger generation in this sector is a concern. However, according to Siregar et al. (2021), the situation holds great potential if developed through technology-based bamboo entrepreneurship and the creativity of young people.

4.8. SWOT Analysis

The results of the SWOT analysis based on the responses of participants in the FGD conducted at the research location are as follows:

Table 4 SWOT Analysis

No.	SWOT Factors	Category	Weight (W)	Score (S)	Value (B x S)
1	Availability of natural bamboo	Strength	0	5	1.0
2	Local knowledge of bamboo	Strength	0.15	4	0.60
3	Community support for conservation	Strength	0	4	0.4
4	Bamboo cultural value	Strength	0.05	4	0.20
5	Low economic contribution	Weakness	0.15	4	0.6
6	Lack of skills & derivative products	Weakness	0.10	4	0.40
7	No bamboo cooperatives	Weakness	0.10	3	0.30
8	Limited market access and tools	Weakness	0.05	3	0.15
9	Potential for a bamboo tourism village	Opportunity	0.20	5	1.00
1	Green economy trend (SDGs)	Opportunity	0.10	4	0.40
11	Collaboration with external partners	Opportunity	0.10	4	0.40
12	Digital market for bamboo	Opportunity	0.10	4	0.40
1	Unsustainable exploitation	Threat	0.10	4	0.40
14	Weak coordination between agencies	Threat	0.10	3	0.30
15	Low interest among young people	Threat	0.10	3	0.3
16	Dependence on external assistance	Threat	0.05	2	0.10

Source: Processing results

Table 5 SWOT Matrix

	Strengths (S)	**Weaknesses (W)**
Opportunities (O)	SO Strategies - Bamboo tourism village - Cultural product branding - University partnerships	WO Strategies - Training in bamboo-based products - Bamboo cooperative - Bamboo e-commerce platform
Threats (T)	ST Strategies	WT Strategies - Continuous mentoring

	- Traditional conservation - Involve traditional leaders - Coordination forum	- Youth digital literacy - Bamboo regeneration system

The table shows that the bamboo development strategy was formulated using a SWOT analysis. The SO strategy leverages strengths and opportunities by promoting the establishment of bamboo tourism villages, culture-based branding, and partnerships with universities. The WO strategy addresses weaknesses by capitalizing on opportunities through training in bamboo-based products, forming bamboo cooperatives, and utilizing e-commerce platforms. To address threats, the ST strategy is implemented through a traditional conservation approach, involving community leaders and establishing a coordination forum. Meanwhile, the WT strategy focuses on institutional strengthening and regeneration through continuous mentoring, digital literacy for youth, and sustainable bamboo system management.

Based on the matrix above, the following Bamboo Development Program Plan is derived:

- Quadrant I – SO Strategy (Strengths–Opportunities) where strengths and opportunities are present → focus on expansion and strengthening potential.

Program	**Key Activities**	**Objectives**	**Output**
Bamboo Tourism Village	- Development of bamboo tourism packages - Training for local tour guides	Tourism awareness groups, local SMEs	Active tourist villages, increased visitor numbers
Cultural Product Branding	- Ethnic bamboo packaging design - Digital marketing based on local stories	Artisans, creative SMEs	Value-added bamboo products & widely recognized
Academic Partnerships	- Research collaboration & campus service- Student internships in bamboo communities	Universities, students, and communities	Technology innovation tailored for bamboo

- Quadrant II – WO Strategy (Weaknesses–Opportunities) There are internal weaknesses, but significant opportunities → focus on capacity building.

Program	**Main Activities**	**Objectives**	**Output**
Bamboo Product Training	- Craft workshop - Modern bamboo processing techniques	Household-based enterprises (IRT), youth, artisans	Skilled human resources, diverse products
Establishment of a Bamboo Cooperative	- Institutionalization awareness - Cooperative management strengthening	Artisan groups	Active and independent cooperatives
Bamboo E-commerce	- Digital marketing support- Local bamboo marketplace	Bamboo SMEs	Online platform for bamboo sales

- Quadrant III – ST Strategy (Strengths–Threats) Strengths are leveraged to address threats → focus on protection & collaboration.

Program	**Main Activities**	**Objectives**	**Output**
Conservation of Traditional Bamboo	- Designation of traditional protected areas - Replanting of bamboo	Traditional leaders, indigenous communities	Sustainable bamboo conservation area
Involvement of Traditional Leaders & Culture	- Community dialogue forums - Role of leaders in bamboo education	Traditional leaders, youth	Cultural support for bamboo conservation

Multi-stakeholder coordination forum	- NGO–Local Government–Community Forum - Integrated planning	Local government, local partners	Policy and program synergy

- Quadrant IV – WT Strategy (Weaknesses–Threats) Weak and threatened conditions → defensive strategies and sustainable development.

Program	**Key Activities**	**Objectives**	**Output**
Continuous Mentoring	- Bamboo village facilitator - Community monitoring and evaluation	Artisans, new entrepreneurs	Program sustainability & knowledge transfer
Youth Digital Literacy	- Digital creativity classes - Bamboo content training	Young people, students	Young people are actively involved in branding & innovation.
Bamboo Regeneration System	- Bamboo seedling nursery - Sustainable planting & harvesting education	Bamboo farmers, rural youth	Sustainable bamboo production cycle

5. Discussion

This study shows that bamboo development is not only about economics, but also about culture, ecology, and social structure. Bamboo has enormous potential, but its realization depends on technical support, institutional frameworks, and affirmative policies. The community has high social capital and conservation awareness, so the appropriate approach is to strengthen local capacity through community-based models. This aligns with various international studies emphasizing the importance of regional innovation, participatory methods, and integrating local and modern knowledge in sustainable development.

The majority of respondents were men over the age of 50 who worked as farmers and had large families to support. These characteristics indicate that the respondents were experienced heads of households with a subsistence lifestyle based on local resources. This supports the Sustainable Livelihood Framework (SLF), which explains that rural households tend to rely on *natural capital* as their primary source of livelihood (DFID, 1999). This condition aligns with Krantz's (2001) findings that rural communities, especially developing countries, are more vulnerable to economic shocks due to their dependence on unoptimally managed natural resources.

As many as 85.2% of respondents use bamboo for daily needs—from construction, food, to art and medicine. This shows that bamboo has strong socio-ecological functions. This supports the findings of Cheng et al. (2023) that bamboo is part of *traditional ecological knowledge* (TEK), which is local knowledge passed down and becomes an integral part of indigenous peoples' lives. Beyond its utilitarian value, bamboo in rituals and traditional architecture highlights its symbolic value, which can be leveraged in eco-cultural tourism approaches, as outlined within the political ecology framework (Robbins, 2012).

Despite its abundance, 74% of respondents reported not receiving significant income contributions from bamboo. Only a small portion produces derivative products, indicating low value addition. This suggests that bamboo's economic potential is latent and has not been capitalized due to weak technical capacity, market access, and policy support. This aligns with the findings of Pieter & Utomo (2023), who emphasize the importance of an industrial ecosystem and affirmative policies in uplifting the micro bamboo sector.

Bamboo is vital in local culture, from traditional houses and musical instruments to rituals. Although not quantified statistically, these findings suggest that bamboo can become a cultural narrative in ecotourism. An eco-cultural tourism approach can combine environmental conservation, local economy, and cultural heritage. Similar research by López-Guzmán et al. (2020) also shows that culture-based tourism can enhance community well-being and preserve local identity.

96.3% of respondents stated they were ready to participate in bamboo business development if facilitated. Social capital in the form of willingness to work in groups, trust among members, and openness to training is the foundation for

community-based development. These findings align with the CBNRM (Community-Based Natural Resource Management) concept, which positions communities as the primary actors in natural resource management (Fabricius et al., 2007).

The joint display approach, which combines quantitative data and qualitative narratives, strengthens insights. For example, although 74% stated that bamboo's economic contribution was low, narratives such as "we do not know how to process it into products" reveal the *root* causes, namely, limited tools and training. This reflects the mixed methods approach that Creswell & Plano Clark (2018) recommended to capture contextual dimensions holistically.

The SWOT analysis conducted in this study identified that the community's main strengths lie in the natural availability of bamboo and locally inherited knowledge, which form an essential basis for community-based resource management. On the other hand, the main weaknesses are the lack of derivative products, low technical skills, and limited market access, which hinder bamboo's contribution to household economies. Meanwhile, external opportunities are wide open, especially in green economy trends, the development of culture-based ecotourism, and partnerships with external institutions such as universities and the private sector. The development strategy is divided into four tactical quadrants in response to these dynamics. The SO (Strength–Opportunity) strategy emphasizes expanding potential by establishing bamboo tourism villages, branding local cultural products, and building academic partnerships for innovation. The WO (Weakness–Opportunity) strategy focuses on strengthening capacity through training in derivative products, forming cooperatives, and digitizing local markets. The ST (Strength–Threat) strategy optimizes local strengths to address challenges by promoting community-based conservation, engaging cultural leaders, and coordinating multi-stakeholder efforts. Meanwhile, the WT (Weakness–Threat) strategy adopts a defensive approach through continuous mentoring, digital literacy for youth, and developing a bamboo regeneration system to ensure sustainable management practices.

This strategic framework aligns with the grassroots innovation approach. This community-based social innovation model emerges from the bottom up and relies on local knowledge and active citizen participation in economic and ecological transformation processes (Seyfang & Smith, 2007). This approach is highly relevant in indigenous communities with strong social structures and high cultural values, as it enables the innovation process to be inclusive, contextual, and sustainable. Seyfang & Smith (2007) emphasize that the success of grassroots innovation lies in the community's ability to organize local resources, strengthen social networks, and generate adaptive solutions to environmental and economic challenges. In the context of bamboo, these strategies point to a transformative path from traditional utilization to value-added and sustainable management.

6. Conclusion

This study successfully formulated community-based bamboo development strategies by considering the socio-ecological context and active participation of indigenous communities in West Papua. The results show that bamboo has long been an integral part of the community's life, serving as a building material, food, household tools, and a cultural symbol in traditional rituals and music. However, bamboo utilization remains subsistence-based and has not contributed significantly to the economy due to low value addition, limited technical training, and the absence of organized market access.

The community's perception of bamboo's economic, social, and ecological value is very high, as evidenced by full support for conservation and enthusiasm for forming bamboo business groups with proper guidance. The potential of bamboo in local economic development is also very promising, particularly through an *eco-cultural tourism* approach that combines ecological values, cultural heritage, and creative economy. The community's expectations for the role of the government and traditional institutions are firm in terms of facilitating training, providing production tools, opening market access, and strengthening local institutions.

Through a SWOT analysis and integrating quantitative and qualitative data, this study develops a strategy based on real conditions in the field, divided into four quadrants. The plan includes the development of bamboo tourism villages, the formation of cooperatives, training in derivative products, strengthening the role of traditional leaders, and a sustainable bamboo regeneration system. This overall strategy forms a community innovation framework (*grassroots innovation)* that enables the transformation from a nature-based consumption system to a culture- and technology-based production system in a participatory and sustainable manner.

Implications

- Theoretical Implications

This study enriches the socio-ecological approach in community development studies by adding a cultural dimension as a driver of the local economy. Another theoretical contribution is strengthening the concepts of grassroots innovation and community-based natural resource management (CBNRM) in the context of indigenous communities, where local knowledge, cultural identity, and social relations are the primary assets for development.

- Practical Implications

The strategies developed can serve as a practical framework for designing community empowerment programs in West Papua. Local governments, NGOs, and universities can utilize the research findings to develop training programs, facilitate bamboo cooperatives, and promote community-based cultural ecotourism. Community involvement from the planning stage is key to ensuring that programs are sustainable and deeply rooted in local values and needs.

- Policy Implications

These findings highlight the urgency for local governments to develop affirmative regulations recognizing bamboo as a strategic cultural commodity. Such policies should support the establishment of traditional bamboo cooperatives, incentives for environmentally friendly bamboo products, and the integration of bamboo into the green economy and regional tourism programs. Strengthening traditional institutions as formal partners in resource management is also critical to future policies.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abadega, D., & Abawaji, T. (2020). *Bamboo development in Ethiopia: Opportunity and challenge*. Ethiopian Forestry Association.

[2] Abdillah, M., Prasetyo, W., & Nurhayati, A. (2023). Community-based skills training in bamboo utilization in marginal areas. *Journal of Community Service, 5*(1), 45–56.

[3] Alamerew, A., Gebeyehu, B., & Kassa, B. (2024). Community-based bamboo development: Challenges and prospects in rural Ethiopia. *International Journal of Rural Development, 12*(2), 78–91.

[4] Anggita, R. P., & Ilyas, M. (2024). Development of bamboo weaving as a creative business in a tourist village. Journal of Social Innovation, 9(1), 33–45.

[5] Berkes, F. (2004). Rethinking community-based conservation. Conservation Biology, 18(3), 621–630. https://doi.org/10.1111/j.1523-1739.2004.00077.x

[6] Cheng, L., Zhang, W., & Xu, Y. (2023). Bamboos and traditional ecological knowledge in rural China. Journal of Rural Studies, 101, 103015. https://doi.org/10.1016/j.jrurstud.2023.103015

[7] Creswell, J. W., & Plano Clark, V. L. (2018). Designing and conducting mixed methods research (3rd ed.). SAGE Publications. https://doi.org/10.4135/9781506335193

[8] DFID. (1999). Sustainable livelihoods guidance sheets. Department for International Development. https://www.ennonline.net/dfidsustainableliving

[9] Fabricius, C., & Koch, E. (2004). Rights, resources, and rural development: Community-based natural resource management in Southern Africa. Earthscan.

[10] FAO & INBAR. (2018). Bamboo and rattan for sustainable development and climate change adaptation. https://www.inbar.int/resources/inbar_publications/bamboo-and-rattan-for-sustainable-development/

[11] INBAR. (2020). Bamboo and sustainable development. International Bamboo and Rattan Organization. https://www.inbar.int/resources/inbar_publications/bamboo-and-sustainable-development/

[12] Krantz, L. (2001). The sustainable livelihood approach to poverty reduction: An introduction. SIDA. https://www.sida.se/contentassets/083bf2c7984b4d6ba4e366fd36a5c4a9/the-sustainable-livelihood-approach-to-poverty-reduction_2656.pdf

[13] Lobovikov, M., Paudel, S., Piazza, M., Ren, H., & Wu, J. (2007). World bamboo resources: A thematic study prepared in the global forest resources assessment framework 2005. FAO Forestry Paper 147. https://www.fao.org/3/a1243e/a1243e00.htm

[14] López-Guzmán, T., Sánchez-Cañizares, S., & Pavón, V. (2020). Community-based cultural tourism and sustainable development: A case study of indigenous communities in Mexico. Tourism Management, 78, 104032. https://doi.org/10.1016/j.tourman.2020.104032

[15] Mishra, B. K., Singh, R. P., & Kumar, A. (2017). Bamboo-based agroforestry systems for soil and water conservation in eastern India. Agroforestry Systems, 91, 209–223. https://doi.org/10.1007/s10457-016-9910-3

[16] Pieter, R., & Utomo, H. (2023). Micro bamboo enterprises in Indonesia: Between policy vacuum and informal resilience. The Journal of Development Studies. https://doi.org/10.1080/00220388.2023.2204502

[17] Prasetyo, A., Wibowo, A., & Wulandari, T. (2021). Challenges and opportunities for bamboo business development in Indonesia. Journal of Forestry Economics, 18(2), 145–160.

[18] Robbins, P. (2012). Political ecology: A critical introduction (2nd ed.). Wiley-Blackwell.

[19] Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. Ecological Economics, 63(4), 706–718. https://doi.org/10.1016/j.ecolecon.2006.12.018

[20] Sharma, C. M., & Bhatt, B. P. (2018). Role of bamboo in soil and water conservation: A review. Indian Forester, 144(3), 245–250.

[21] Siregar, Y., Nasution, D. A., & Marpaung, R. M. (2021). Revitalizing the role of the younger generation in a sustainable bamboo economy. Jurnal Ekonomi Hijau, 6(2), 101–114.

[22] Soetjipto, R. A., Hutabarat, R. L., & Lestari, R. (2019). Bamboo construction in Indonesian culture. Jurnal Arsitektur Nusantara, 5(1), 23–31.

[23] Soliven, R., Acosta, R., & Balbarino, M. (2024). Bamboo enterprise development in the Philippines: Policy, practice, and innovation. Asian Journal of Forestry Policy, 10(1), 56–72.

[24] UNDRIP. (2007). United Nations Declaration on the Rights of Indigenous Peoples. https://www.un.org/development/desa/indigenouspeoples/declaration-on-the-rights-of-indigenous-peoples.html

[25] Zhang, Y., & Jiang, H. (2019). Bamboo root systems and their role in soil erosion control: A review. Plant and Soil, 437, 95–108. https://doi.org/10.1007/s11104-019-03941-6

[26] Zhou, Y., Wang, G., & Wu, J. (2022). Bamboo forests as nature-based solutions to climate change mitigation and adaptation. Science of The Total Environment, 838, 155841. https://doi.org/10.1016/j.scitotenv.2022.155841

Appendix

SWOT Analysis of Community-Based Bamboo Development in West Papua

Strengths (Strengths)

No	Key Strengths	Explanation
1	Availability of natural bamboo resources	Bamboo grows naturally and is widely distributed in indigenous areas without intensive cultivation.
2	Strong local knowledge of bamboo species and uses	Communities are familiar with various types of bamboo (e.g., Bajarek, Kebwar, Ibwar) and their cultural uses.

3	Community support for conservation and preservation	100% of respondents support bamboo conservation, indicating high ecological awareness.
4	Deep cultural value connections	Bamboo is used in traditional rituals, traditional music, and traditional houses, making it a symbol of local culture.

Weaknesses

No	Main Weaknesses	Explanation
1	Low economic contribution of bamboo to household income	74% of respondents stated that bamboo has not provided significant income (less than 25% of total income).
2	Lack of technical skills and product diversification	Few residents make woven goods or handicrafts; regular training is unavailable.
3	Absence of community economic institutions such as bamboo cooperatives	The absence of institutional frameworks results in unorganized production and distribution.
4	Limited access to markets and technology	Most respondents do not sell bamboo because they do not have access to markets and production tools.

Opportunities

No	Strategic Opportunities	Explanation
1	Development of a bamboo-based cultural and educational tourism village	Potential to highlight bamboo as an eco-tourism attraction that combines tradition, music, and crafts.
2	Support for global trends toward green economy and sustainable development (SDGs)	Bamboo is promoted internationally as an environmentally friendly material and a solution to climate change.
3	Possibilities for collaboration with NGOs, universities, and CSR practitioners	Various parties can play a role in training, research, financing, and branding local bamboo.
4	Digital markets and e-commerce for bamboo crafts	Opportunities to expand the marketing of bamboo-based products through online platforms (Tokopedia, Shopee, etc.).

Threats

No	Potential Threats	Explanation
1	Risk of exploitation without conservation	Increased utilization without sustainable management can lead to the degradation of bamboo forests.
2	Weak coordination among stakeholders	Lack of synergy between the government, indigenous communities, NGOs, and the private sector can hinder development.
3	Lack of interest among the younger generation in the bamboo sector	This sector is considered "traditional" and unpromising by the younger generation without innovation.
4	Reliance on external assistance	The program's sustainability may be halted if there is no continuity of local institutions.

Strategic Implications of the SWOT Analysis

Based on the SWOT map above, the strategies that can be adopted focus on internal strengthening (S + O) and risk mitigation through a W + T approach, as follows:

Strategy	SWOT Formula	Policy/Program Direction
Development of bamboo tourism villages	Strength + Opportunity	Combination of cultural value and eco-tourism potential → bamboo village branding
Technical training and bamboo cooperatives	Weakness + Opportunity	Addressing skill and market limitations through collaborative training and mentoring
Community-based conservation	Strength + Threat	Local awareness is leveraged to prevent exploitation and ecological degradation.
Digital technology-based innovation	Weakness + Threat	Avoiding falling behind through product digitalization and online marketing