



Linking Agroecology, Livelihoods, and Sustainability in Community Forests: Insights from Bukit Daun and Bukit Balai Rejang Protected Forest, Bengkulu, Indonesia

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Abstract

Community forestry in Indonesia has been promoted to strengthen rural livelihoods while conserving forest ecosystems. However, its sustainability remains uncertain due to ecological vulnerabilities and socio-economic dependence. This study analyzes the sustainability of community forestry in the Bukit Daun and Bukit Balai Rejang Protected Forests, Bengkulu Province, by linking agroecological principles with the Sustainable Livelihoods Approach. Primary data were collected from 308 households across 16 Forest Farmer Group Associations through structured interviews. A composite sustainability index was developed using MCDA, and causal relationships were examined through SEM-PLS. The findings show that its sustainability is primarily driven by biodiversity, soil and water conservation, market access, and cultural-cognitive pillars of institutional arrangements, while technological innovation and social participation contribute more marginally. Agroecological principles and livelihood resources significantly enhance sustainability, both directly and indirectly, with agroforestry revenue serving as a key mediator. Subjective well-being exerts a direct positive effect on sustainability, underscoring the psychosocial aspects of resilience. This study demonstrates that sustaining community forestry requires not only ecological practices and livelihood diversification but also stronger regulatory institutions, technological innovation, and inclusive participation. The findings contribute to global debates on community-based forestry by demonstrating how local agroecological practices and livelihood assets can secure both community welfare and ecological integrity.

Keywords: community forests, agroecology, livelihoods, sustainability, forestry governance

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Introduction

In many Global South countries, forests are not just carbon sinks or protected areas but also sources of livelihood, local knowledge, and tenure claims that are historically rooted in indigenous and local communities (Erbaugh et al., 2020). The recognition of community rights and the implementation of community-based forest management schemes contribute to the conservation and improvement of local well-being (Fischer et al., 2023). In Indonesia, evidence from social forestry and community-based forest management programs suggests that granting communities access rights, management authority, and technical support can simultaneously strengthen livelihood security and support forest conservation outcomes (Harbi et al., 2020). Community-based forest concession practices in Guatemala, as well as studies across Asia and Africa, confirm that when access and management rights are fairly regulated and formally institutionalized, forest cover and carbon stocks tend to be better maintained while still generating economic benefits for local communities (Wood et al., 2019; vonHedemann, 2022).

The Food and Agriculture Organization (FAO) and the global scientific community emphasize that tenure security

and meaningful community participation are key prerequisites for successful sustainable forest management (Rakotonarivo et al., 2023). In line with that, the IPCC affirms that approaches that integrate climate change mitigation with community-based adaptation have great potential to increase socio-ecological resilience while lowering the rate of tropical deforestation (Few et al., 2017).

For the Government of Indonesia, social forestry has become an important strategy to improve the socio-economic conditions of forest-dependent communities while strengthening the conservation and sustainability of forest management (Makkarennu et al., 2024). Since its launch, its performance has shown significant improvement, from 653.31 ha in 2014 to 3.37 million ha in 2019 (Sahide et al., 2020) and reaching 8.30 million ha in 2024 (Kementerian Kehutanan, 2025). This program is implemented through various schemes, including village forests, community forests (CF), community plantation forests, forestry partnerships, and customary forests (Samek et al., 2022). These schemes are designed to empower local communities to manage forest resources while providing economic benefits. One of the important instruments is the Community Forest Utilization Business Permit (CFUBP), which grants

management rights for 35 years with evaluation every five years to ensure sustainable practices (Latifah et al., 2023).

Despite the expansion, the implementation of social forestry in Indonesia has faced challenges. These schemes have not fully addressed tenure conflicts and often struggle to engage local communities, especially those experiencing poverty and socio-economic vulnerability (Ragandhi et al., 2021; Widiono et al., 2024a). This leads to a diminished capacity for community participation in CF management (Maryudi, 2022). Additionally, while social forestry has contributed to deforestation reduction, it does not guarantee long-term improvements in forest quality, especially in the face of agricultural expansion (Porter-Bolland et al., 2012; Meijaard et al., 2021).

Unclear tenure rights, thin accountability, and governance arrangements that do not quite match local needs and interests can turn forest management into an uncertain space, where authority is disputed, incentives blur, and day-to-day decisions become harder to sustain (Rachmawan et al., 2021; Widiono et al., 2024b). Similar challenges have been linked to ambiguous forest boundaries and unclear property rights (Harbi et al., 2021), often resulting in social conflicts and governance inefficiency (Maring, 2022; Widiono, 2024). Rather than advancing community empowerment, these programs often pivot toward meeting administrative benchmarks and extending state oversight of local communities (Sahide et al., 2020).

This dynamic becomes especially legible in Bengkulu Province, a jurisdiction where forest canopy still occupies a substantial share of the territory, about 46.1% of the provincial area. In the 2021–2022 period, deforestation in this province reached 4,762.3 ha, an increase of 6.9% compared to the previous year (Badan Pusat Statistik, 2024). A study by Oktoyoki et al. (2023) shows that there are still obstacles, including low participation and representation of women, weak group administration, absence of independent forestry extension workers, lack of clear mapping of managed areas, limited capital, weak product standardization, lack of business diversification, and lack of partnerships.

According to Pambudi (2020), top-down approaches to forest management have marginalized the role of local communities and widened the gap between national policies and realities at the site level. Ironically, the program has not yielded satisfactory progress in poverty reduction or environmental sustainability (Pratama, 2019), and its benefits remain unevenly distributed, registering for some groups but not being comparably felt by farmers whose livelihoods hinge on forest resources (Rachmawan et al., 2021). This situation is counterproductive to the former goal of social forestry designation. Taken together, this pattern reinforces the case for a more inclusive, participatory, and landscape-based governance model: not merely to secure conservation gains, but to carry them forward alongside the strengthening of local livelihoods (Harbi et al., 2020).

Various studies have shown that social forestry contributes to improving people's livelihoods and reducing deforestation (Rachmina et al., 2024; Toumbourou et al., 2025). However, a number of studies have also found various indications of unsustainability in the social, ecological, economic, technological, and institutional dimensions

(Santika, 2019; Gunawan et al., 2022; Rochmayanto et al., 2023). In the context of these challenges, the studies that explain the factors that shape the sustainability of social forestry and how these factors can be translated into effective governance strategies have not been found.

To address this gap, an analytical framework is needed that is not only able to assess sustainability conditions, but also explain the relationship between ecological systems, people's livelihood resources, and underlying institutional governance. This study offers an alternative approach based on traditional agroecological practices and the Sustainable Livelihoods Approach (SLA) as a conceptual foundation in understanding the sustainability of community forestry and formulating its governance strategies. Agroecology applies ecological principles through diversified cropping, low external inputs, and resource conservation (Altieri, 1996; Vikas & Ranjan, 2024). Meanwhile, the SLA highlights the importance of access to and management of five types of livelihood resources—natural, physical, financial, human, and social—that are closely linked to local relationships and institutions (Scoones, 2015). Integrating these two approaches is expected to provide a substantive contribution to the initiation of a networked governance strategy (Rhodes, 2017), which strengthens institutions, encourages livelihood diversification, increases resilience, and expands people's adaptation capacity to socio-economic and ecological changes. In the context of agroforestry, local wisdom and socio-economic factors are intertwined with ecological factors that form a sustainable land management system (Pribadi et al., 2023; Padmaningrum et al., 2024). Accordingly, agroecology-based governance and the SLA are positioned as a strategy to strengthen agricultural productivity, fortify livelihood resilience, and advance the welfare of forest-adjacent communities.

Methods

A brief description of the research area The Bukit Daun Protected Forest area has an area of ±96,125 ha spread across five regions in Bengkulu Province, namely North Bengkulu (43,212 ha), Lebong (17,558 ha), Rejang Lebong (4,897 ha), Kepahiang (8,086 ha), and Central Bengkulu (22,372 ha). This area is not only important as a water catchment area for 19 watersheds, including the Musi watershed, but also a strategic location for the implementation of social forestry. Through the CF scheme, 42 permits have been issued with a total area of ±21,174.14 ha, involving 6,507 households as beneficiaries. This scheme allows communities to legally manage protected forests for non-timber forest products (NTFP) like durian bentara, pine sap, and coffee agroforestry. Social forestry in Bukit Daun helps keep the area safe for the environment and acts as a place for studying and developing sustainable ways for local communities to make a living.

The Bukit Balai Rejang Protected Forest area managed by the Protected Forest Management Unit (PFMU) of Bukit Balai Rejang is an important part of the Bukit Barisan landscape in Bengkulu Province, covering the areas of Sindang Beliti Ilir, Sindang Beliti Ulu, and Kota Padang. As of August 2024, there are 6 decrees of social forestry permits that have been granted in this area, with a total area of 2,564 ha and involving 472 households. Its management unit consists of several Forest Farmer Group Associations

(FFGA) of CF and Village Forest Management Institutions at the village level, which are granted management rights to develop agroforestry practices, the use of NTFPs, and community-based conservation activities. The Bukit Balai Rejang forests function vitally as a protected area that maintains water systems, prevents erosion, and supports the biodiversity typical of the Bukit Barisan mountains.

The research was conducted purposively at the locations of the CF program in the Bukit Daun and Balai Rejang Protected Forest areas in Rejang Lebong Regency and the Bukit Daun Protected Forest area in Lebong Regency, Bengkulu Province, Indonesia (Figure 1). The landscape is characterized by a mosaic of agricultural and residential land uses. Small-scale coffee-based agroforestry dominates the upland areas and is a major source of livelihood for local communities. In addition, rainfed rice fields are found at the bottom of lower valleys and slopes, while rural settlements are concentrated along transportation corridors and near agricultural production areas. There are 5 FFGA in Rejang Lebong that received CFUBP in 2015 and 2 FFGA in 2019. Meanwhile, in Lebong, CFUBP for 8 FFGA came out in 2015 and 1 in 2022. The initiation and assistance until the issuance of the permit were carried out by the Non-governmental Organization (NGO) of the Akar Global Initiative based in Bengkulu. Their total permit area in Rejang Lebong Regency is 1,980.61 ha and Lebong 4,516.96 ha.

Data collection Primary data were collected through structured, questionnaire-based home interviews of about 40 minutes. The survey mapped socio-demographic profiles, surfaced perceptions of agroecological principles, and rendered legible agroforestry and non-agroforestry production, household income, access to livelihood resources, subjective well-being, and perceived sustainability

dimensions. Short, but essential. Before data were elicited, informed consent was secured through an explanation of the study aims: not merely as a procedural step, but as a commitment to voluntariness, confidentiality, and anonymity.

Respondents were selected through stratified random sampling by CFUBP age, classifying FFGA as old, more than 6 years, from CFUBP 2015, or new, 6 years or less, from CFUBP 2019 and 2022. In total, 308 respondents were distributed almost proportionally across FFGA members at each site (Table 1). Their characteristic is presented in Table 2.

Data analysis Sustainability index analysis This analysis applied Multi-Criteria Decision Analysis (MCDA) using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to integrate social, ecological, economic, technological, and institutional indicators into a composite sustainability index for CF groups. TOPSIS ranks alternatives based on their closeness to the positive ideal and distance from the negative ideal solution (Zlaugotne et al., 2020). The resulting Closeness Coefficient (CC) indicates sustainability levels, with values near 1 showing high sustainability and values near 0 indicating low sustainability. The CC is calculated by Equation [1].

$$CC = \frac{D_i^-}{D_i^+ + D_i^-} \quad [1]$$

The distance to positive and negative solutions is determined by calculating the Euclidean distance (D_i) on each dimension of sustainability (Equation [2] & Equation [3]). To avoid different scales, each indicator is normalized with the vector standardization technique. Additionally, each indicator is weighted using the Bayes method, which involves discussions with experts in the fields of sociology of

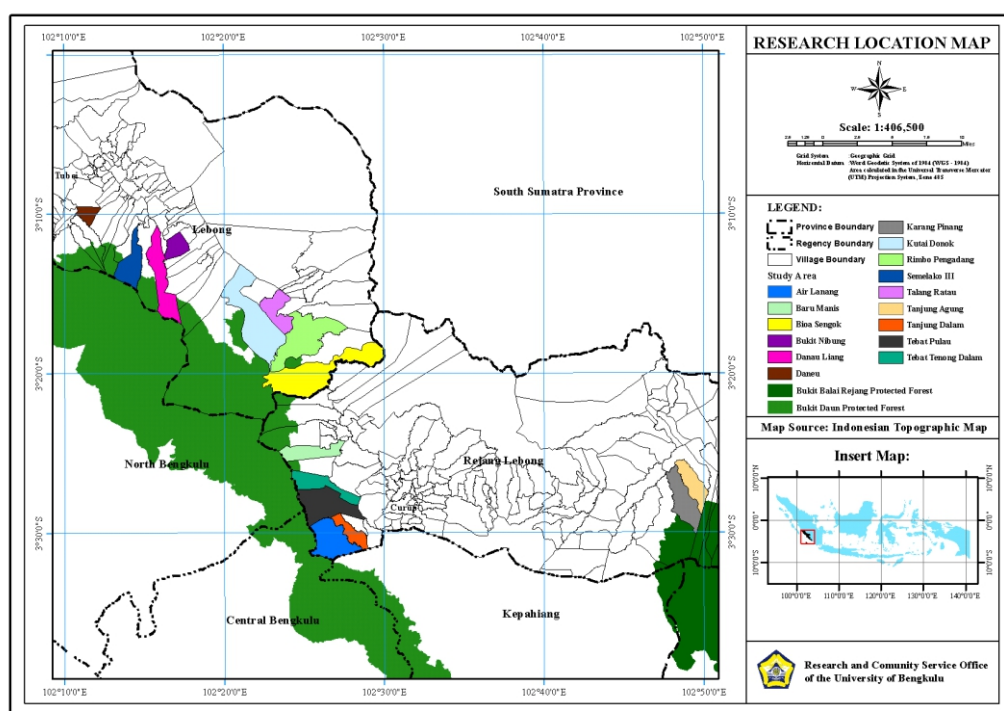


Figure 1 Research location map.

Table 1 Distribution of research respondents

FFGA name	Village	Forest area	CFUBP category	FFGA members	Respondents
Tumbuh Lestari	Air Lanang	Bukit Daun	Old	68	10
Maju Jaya	Tanjung Dalam	Bukit Daun	Old	95	13
Tri Setia	Tebat Pulau	Bukit Daun	Old	296	37
Rukun Makmur	Baru Manis	Bukit Daun	Old	156	21
Enggas Lestari	Tebat Tenong Dalam	Bukit Daun	Old	106	15
Karang Bak	Karang Pinang	Bukit Balai Rejang	New	127	15
Moneng Lebui	Tanjung Agung	Bukit Balai Rejang	New	103	15
Sedasen	Talang Ratu	Bukit Daun	Old	78	11
Bioa Sengok	Air Dingin	Bukit Daun	Old	175	23
Telaga 7 Warna	Air Dingin	Bukit Daun	New	77	11
Bioa Smatung	Daneu Liang	Bukit Daun	Old	299	25
Tebo Amen	Semelako III	Bukit Daun	Old	159	21
Bukit Aning Aning	Rimbo Pengadang	Bukit Daun	Old	307	30
Bukit Agung	Bukit Nibung	Bukit Daun	Old	113	15
Bukit Indah	Kota Donok	Bukit Daun	Old	255	32
Pabes Jaya	Daneu	Bukit Daun	Old	100	14
Total					308

Table 2 Socio-demographic profile of respondents

Characteristic	Number
Number of respondents	308 (Old permit = 267, New permit = 41)
Age (mean ± stdev; years)	46.18 ± 9.35
Gender:	
- Male	279 (90.58%)
- Female	29 (9.42%)
Education:	
- No school	11 (3.57%)
- Primary school	67 (21.75%)
- Secondary school	117 (37.99%)
- Senior high school	112 (36.36%)
- University	1 (0.32%)
Marriage status:	
- Married	295 (95.78%)
- No marry	6 (1.95%)
- Widow/Widower	7 (2.27%)
Family size (mean ± stdev)	4.03 ± 0.98
Farming area in CF (mean ± stdev; ha)	1.95 ± 0.24
Farming area outside CF (mean ± stdev; ha)	0.53 ± 0.76

forest communities, agroforestry, natural resource economics, and forest area stakeholders. The weights were social (0.192), ecology (0.202), economy (0.209), technology (0.190), and institutional (0.207). Each indicator is measured on a Likert scale (score 15).

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, \quad [2]$$

$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, \quad [3]$$

Sustainability modeling Modeling was conducted using SEM-PLS to examine causal relationships between latent and manifest constructs within the frameworks of agroecology and the SLA, assessing their effects on CF sustainability. The procedure involved two stages: evaluating the outer model for validity and reliability (convergent validity, discriminant

validity, and construct reliability) and assessing the inner model for fit and significance of structural relationships. Analysis was performed with SmartPLS v.3.2.9. Correlations among latent constructs were tested using the bootstrapping technique with the significant level at 0.05 (p -value ≤ 0.05). The structural model comprises six latent constructs connected through direct and indirect paths (Figure 2), each measured by several reflective indicators derived from sub-indicators (Table 3).

Results

Sustainability status of community forests *Indexing and mapping of sustainability* The results of the sustainability calculation are obtained as per Table 4, and the spatial distribution is presented in Figure 3. The color gradations show the sustainability level order, where green indicates a

Table 3 List of constructs, indicators, and sub-indicators in the model

Constructs	Indicators	Sub-indicators
Agroecology principles (X1)	Biomass recycling (X1.1)	Utilization of leaf/twig/organic matter litter as mulch; avoiding litter burning & coffee crop waste
	Agricultural immune system (X1.2)	Number of protective plants (intercrops)
	Favorable soil conditions (X1.3)	Avoid tillage on the riparian zone; minimal tillage; coffee planting distance
	Minimization of energy, water, nutrients and genetic resources losses (X1.4)	Vegetation cover; planting following the contours of the soil; avoiding the slash-burn technique
	Species and genetic resources diversification (X1.5)	Diversity of vegetation strata
	Beneficial biological interactions and synergies (X1.6)	Wildlife diversity
Livelihood resources (X2)	Natural capital (X2.1)	Agricultural land area; land availability, natural resource availability; river conditions
	Physical capital (X2.2)	Type of house; floor area; condition of farming road; travel time to agricultural land
	Financial capital (X2.3)	Amount of savings; access to financial institutions; use of credit; ability to access financial resources
	Human capital (X2.4)	Number of productive-age family member; family Education; skills other than farming; non-formal education
	Social capital (X2.5)	Participation in community groups; breadth of networking; trust in mutual aid, participation in community meetings; role of social networks
Agroforestry revenue (Y1)	Main crop revenue (Y1.1)	Revenue of coffee plants
	Intercrop revenue (Y1.2)	Revenue of intercropping
Non-agroforestry revenue (Y2)	Non-agroforestry revenue (Y2.1)	Revenue from livestock; non-agricultural businesses; fixed/non-fixed wages
Subjective well-being (Y3)	Life satisfaction (Y3.1)	Satisfaction with agroclimatological conditions, land tenure, transportation access, crop yields, selling prices, income, and employment
	Positive affect (Y3.2)	Happiness at harvest; pride in work; confidence in the future; optimism in agroforestry;
	Negative affect (Y3.3)	Worries about fluctuations in coffee prices; worries about crop failure; feelings of work stress; worries about not being able to meet the needs of life
	Meaning and purpose (Y3.4)	The meaning of coffee plantation business as a family inheritance; usefulness as a coffee farmer; feeling valued as a coffee farmer; and a feeling of pride if the coffee yields are good
Sustainability (Y4)	Social dimension (Y4.1)	Participation of forest farmer group (FFG) members; agroforestry capacity; advocacy and negotiation capacity; legal and policy literacy; tenure conflict
	Ecological dimension (Y4.2)	Biodiversity; soil and water conservation; agroecosystem resilience

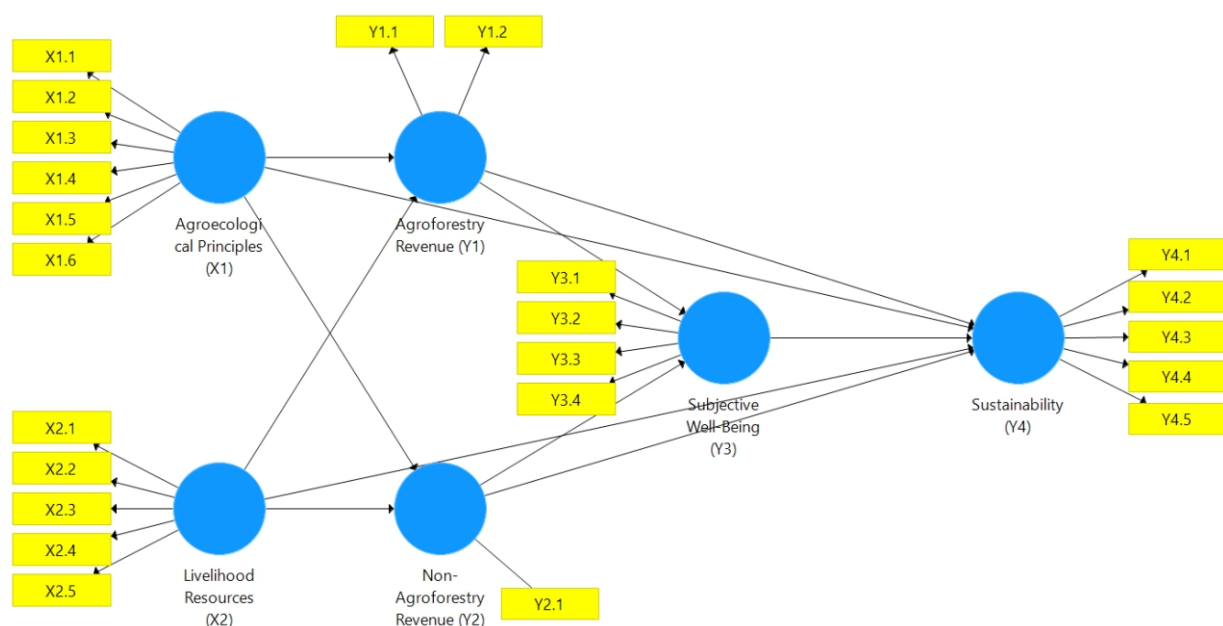


Figure 2 Structural model of community forest sustainability.

high sustainability index and red means the lowest sustainability. As a result, three FFGAs with the best sustainability status were Maju Jaya, Rukun Makmur, and Moneng Lebui. All of them are in Rejang Lebong Regency. In contrast, the three FFGAs with the worst sustainability status are Tebo Amen, Bioa Smatung, and Bukit Aning-Aning, which are in Lebong Regency.

Elaborating sustainability components Social dimension

This study found that the average social dimension score showed varied results (Table 5). In general, the legal and policy literacy indicators were the strongest aspects (3.81); agroforestry capacity is at a sufficient level (3.51); FFG member participation and advocacy & negotiation capacity are relatively moderate (3.03 and 2.92, respectively); and tenure conflict is the indicator with the lowest (1.94). This shows that socially, communities already have the strength to understand rules and governance but still face serious challenges to effective participation, advocacy, and conflict management. Despite the low score, tenure conflicts are still a serious problem that can hinder sustainability.

Ecological dimension The sustainability of CF is quite good, with strength in biodiversity and soil and water conservation (Table 6). The main challenge lies in the resilience of

agroecosystems that are still vulnerable. Most FFGAs have maintained the diversity of crops and agroforestry systems, although there are groups with limited diversity. Conservation practices are relatively strong, especially in groups that have experience in terrace techniques, ground cover tree planting, and spring protection. However, there is FFGA whose practice is still not optimal. The resilience of agroforestry systems to pests, diseases, and climate change still varies. Some groups have shown better adaptive capacity, but some are still vulnerable.

Economic dimension Some indicators of economic sustainability are quite good, such as market access (3.83) and local economic stability (3.34). Weak indicators include independence of production inputs (2.60) and diversification of sources of income (2.86). Business efficiency is quite varied. Groups with good internal organization can achieve higher productivity, while those with less management face inefficiency. The economic impact of CF on household income is still limited and varies among FFGA (Table 7).

Technology dimension The measurement results show that the technology dimension is in the medium category (Table 8). The indicator with a relatively higher score was the use of appropriate technology (3.31), followed by technology

Table 4 Sustainability status ranking

FFGA	Village	D+	D-	CC	Rank
Maju Jaya	Tanjung Dalam	0.002	0.031	0.936	1
Rukun Makmur	Baru Manis	0.003	0.031	0.905	2
Moneng Lebui	Tanjung Agung	0.006	0.028	0.812	3
Tri Setia	Tebat Pulau	0.010	0.024	0.694	4
Bioa Sengok	Air Dingin	0.014	0.019	0.571	5
Karang Bak	Karang Pinang	0.015	0.020	0.567	6
Telaga 7 Warna	Air Dingin	0.015	0.020	0.565	7
Tumbuh Lestari	Air Lanang	0.018	0.015	0.465	8
Enggas Lestari	Tebat Tenong Dalam	0.019	0.016	0.458	9
Bukit Agung	Bukit Nibung	0.019	0.014	0.426	10
Sedasen	Talang Ratu	0.023	0.011	0.329	11
Pabes Jaya	Daneu	0.028	0.006	0.170	12
Bukit Indah	Kota Donok	0.029	0.005	0.157	13
Bukit Aning Aning	Rimbo Pengadang	0.029	0.005	0.148	14
Bioa Smatung	Daneu Liang	0.030	0.004	0.125	15
Tebo Amen	Semelako III	0.031	0.004	0.106	16

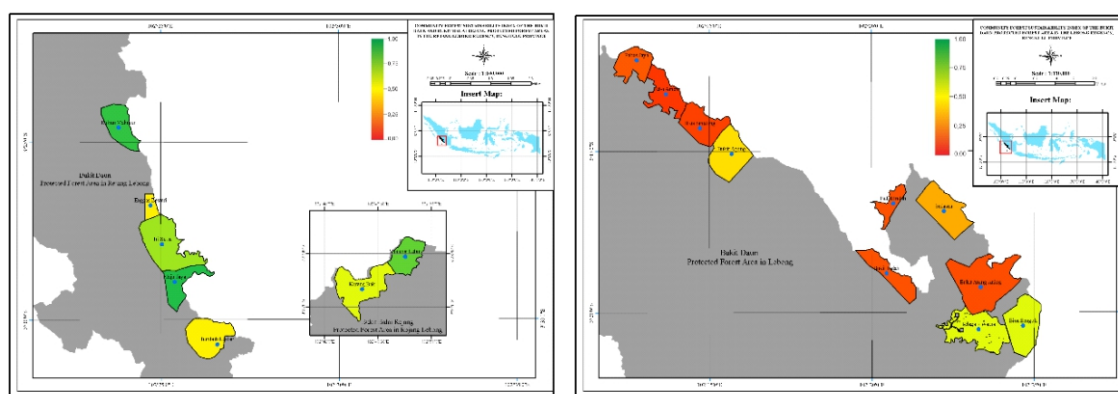


Figure 3 Community forest sustainability map of the Bukit Daun and Bukit Balai Rejang protected forest area

Table 5 Social dimension sustainability score

FFGA	FFG participation	Agroforestry capacity	Advocacy & negotiation capacity	Legal & policy literacy	Tenure conflict
Bioa Sengok	3.78	3.87	2.96	4.04	1.81
Bioa Smatung	1.96	3.13	2.72	3.63	2.76
Bukit Agung	3.20	3.16	3.00	3.84	2.00
Bukit Aning Aning	1.43	2.99	2.45	3.60	1.67
Bukit Indah	2.56	2.78	2.80	3.67	2.15
Enggas Lestari	3.67	3.91	2.47	4.00	1.84
Karang Bak	3.40	3.44	3.33	3.76	1.87
Maju Jaya	3.62	4.28	3.62	4.28	1.87
Moneng Lebui	4.00	4.07	3.43	4.11	1.78
Pabes Jaya	2.79	3.12	2.57	3.52	2.14
Rukun Makmur	3.90	4.24	3.45	4.38	1.75
Sedasen	2.27	3.24	2.82	3.79	1.85
Tebo Amen	2.29	3.19	2.45	3.49	1.92
Telaga 7 Warna	3.45	4.12	3.45	3.76	1.64
Tri Setia	3.84	3.91	2.95	3.77	1.81
Tumbuh Lestari	3.60	3.57	3.15	3.63	1.93
Total	3.03	3.51	2.92	3.81	1.94

Table 6 Ecological dimension sustainability score

FFGA	Biodiversity	Soil & water conservation	Agroecosystem resilience
Bioa Sengok	4.04	4.07	3.61
Bioa Smatung	3.64	3.92	3.40
Bukit Agung	3.80	3.80	3.28
Bukit Aning-Aning	3.42	3.87	3.24
Bukit Indah	3.67	3.99	3.34
Enggas Lestari	3.97	3.97	3.41
Karang Bak	4.03	3.55	3.01
Maju Jaya	4.46	4.15	3.46
Moneng Lebui	4.30	3.90	3.31
Pabes Jaya	3.86	3.57	3.34
Rukun Makmur	4.29	4.10	3.50
Sedasen	3.73	3.93	3.24
Tebo Amen	3.64	3.83	3.41
Telaga 7 Warna	4.23	4.23	3.76
Tri Setia	4.08	3.82	3.34
Tumbuh Lestari	3.70	3.80	3.42
Total	3.89	3.91	3.37

Table 7 Economic dimension sustainability score

FFGA	Business efficiency & productivity	Production input independence	Market access	Increased household income	Intercrops contribution	Local economic stability
Bioa Sengok	3.30	3.13	3.72	3.00	2.83	3.74
Bioa Smatung	3.08	1.80	3.94	3.28	2.40	3.28
Bukit Agung	3.27	2.13	3.93	3.27	3.20	3.33
Bukit Aning-Aning	3.27	2.07	4.12	3.07	2.63	3.00
Bukit Indah	2.91	1.91	3.84	2.94	2.56	2.56
Enggas Lestari	2.93	2.07	3.30	2.33	3.07	4.00
Karang Bak	3.40	3.60	4.00	3.00	2.87	3.07
Maju Jaya	4.00	3.77	4.12	3.08	3.15	3.92
Moneng Lebui	3.60	3.47	3.83	3.40	3.47	3.73
Pabes Jaya	2.64	2.21	3.61	2.86	2.71	2.93
Rukun Makmur	3.71	3.67	4.05	3.05	2.95	3.57
Sedasen	3.55	1.64	4.00	3.64	2.91	3.00
Tebo Amen	2.81	1.90	3.88	2.76	2.38	3.05
Telaga 7 Warna	3.09	3.45	3.64	3.00	3.18	3.82
Tri Setia	3.32	3.14	3.65	3.14	3.11	3.59
Tumbuh Lestari	3.00	2.30	3.35	3.30	3.40	3.90
Total	3.23	2.60	3.83	3.06	2.86	3.34

transfer among members (3.13) and conformity to socio-cultural conditions (3.13). Meanwhile, access to technology (2.89) and local technological innovation (2.92) were the weakest points. This condition shows that although communities are starting to use simple technologies in CF management, accessibility is still limited, conformity with local practices is not fully guaranteed, and innovations emerging from the communities themselves are still minimal.

Institutional dimension The results indicate the average scores of the cultural-cognitive pillars (3.94), normative (3.45), and regulative (3.03). This indicates that the community's values, beliefs, and cultural practices are relatively robust, social norms are functioning adequately, while formal regulatory mechanisms are the weakest aspect due to incomplete and inconsistently applied institutional

documents. Consequently, the institutional sustainability still only relies predominantly on the values, norms, and local identity of FFG members (Table 9).

Structural model of community forest sustainability

Outer model test Indicator and construct validity test

Convergent validity was assessed using outer loadings, which measure the correlation between each indicator and its construct. According to Hair et al. (2011), indicators with loading values below 0.50 are considered invalid. Five indicators (*X1.3*, *X1.4*, *X2.2*, *X2.4*, and *Y3.1*) showed values below this threshold and were therefore removed. The subsequent validity test (phase 2) confirmed that the remaining indicators were valid (Table 10).

The construct validity was assessed using the Average Variance Extracted (AVE) (Table 10), where a construct is considered valid if $AVE > 0.50$. All constructs met this

Table 8 Technology dimension sustainability score

FFGA	Use of appropriate technology	Access to technology	Peer-to-peer technology transfer	Compatibility with Local socio-cultural	Local technological innovation
Bioa Sengok	3.39	2.89	3.22	3.04	3.11
Bioa Smatung	3.12	2.70	2.64	3.04	2.32
Bukit Agung	2.97	2.93	3.07	3.40	2.47
Bukit Aning Aning	3.13	2.73	2.70	2.87	2.45
Bukit Indah	3.45	2.67	3.13	3.03	2.56
Enggas Lestari	2.93	2.83	3.67	2.80	3.10
Karang Bak	3.07	2.63	3.33	3.40	3.37
Maju Jaya	4.00	3.35	3.54	3.31	3.08
Moneng Lebui	3.40	3.23	3.47	3.13	3.47
Pabes Jaya	3.07	3.00	2.57	3.07	2.50
Rukun Makmur	3.79	3.40	3.43	3.52	3.48
Sedasen	3.09	2.59	2.45	3.18	2.41
Tebo Amen	3.10	2.71	2.62	2.81	2.31
Telaga 7 Warna	3.68	2.77	2.73	3.18	3.09
Tri Setia	3.46	3.07	3.68	3.49	3.66
Tumbuh Lestari	3.30	2.70	3.80	2.60	3.70
Total	3.31	2.89	3.13	3.13	2.92

Table 9 Institutional dimension sustainability score

FFGA	Regulative pillar	Normative pillar	Cultural-cognitive pillar
Bioa Sengok	3.38	3.49	4.03
Bioa Smatung	1.89	2.90	3.99
Bukit Agung	3.17	3.71	3.80
Bukit Aning Aning	2.01	3.11	3.54
Bukit Indah	1.80	3.20	3.71
Enggas Lestari	3.68	3.33	3.73
Karang Bak	3.68	3.68	4.27
Maju Jaya	4.40	4.15	4.18
Moneng Lebui	4.17	3.97	4.29
Pabes Jaya	2.20	3.20	4.05
Rukun Makmur	4.48	4.17	4.29
Sedasen	2.98	3.49	3.67
Tebo Amen	1.92	2.90	3.71
Telaga 7 Warna	3.16	3.31	3.91
Tri Setia	4.04	3.80	4.08
Tumbuh Lestari	3.10	3.24	4.07
Total	3.03	3.45	3.94

Table 10 Outer loading value in convergent validity test

Construct	Indicator	Phase 1		Phase 2		AVE	Description
		Loading factor	Description	Loading factor	Description		
Agroecological principles (<i>X1</i>)						0.510	Valid
	<i>X1.1</i>	0.746	Valid	0.753	Valid		
	<i>X1.2</i>	0.513	Valid	0.509	Valid		
	<i>X1.3</i>	0.088	Invalid	-	Deleted		
	<i>X1.4</i>	0.101	Invalid	-	Deleted		
	<i>X1.5</i>	0.702	Valid	0.705	Valid		
	<i>X1.6</i>	0.849	Valid	0.846	Valid		
Livelihood resources (<i>X2</i>)						0.579	Valid
	<i>X2.1</i>	0.740	Valid	0.785	Valid		
	<i>X2.2</i>	0.203	Invalid	-	Deleted		
	<i>X2.3</i>	0.607	Valid	0.603	Valid		
	<i>X2.4</i>	0.463	Invalid	-	Deleted		
	<i>X2.5</i>	0.855	Valid	0.871	Valid		
Agroforestry revenue (<i>Y1</i>)						0.602	Valid
	<i>Y1.1</i>	0.919	Valid	0.921	Valid		
	<i>Y1.2</i>	0.600	Valid	0.596	Valid		
Non-agroforestry revenue (<i>Y2</i>)						1.000	Valid
	<i>Y2.1</i>	1.000	Valid	1.000	Valid		
Subjective well-being (<i>Y3</i>)						0.688	Valid
	<i>Y3.1</i>	0.464	Invalid	-	Deleted		
	<i>Y3.2</i>	0.812	Valid	0.809	Valid		
	<i>Y3.3</i>	0.140	Invalid	-	Deleted		
	<i>Y3.4</i>	0.845	Valid	0.849	Valid		
Sustainability (<i>Y4</i>)						0.586	Valid
	<i>Y4.1</i>	0.852	Valid	0.851	Valid		
	<i>Y4.2</i>	0.530	Valid	0.530	Valid		
	<i>Y4.3</i>	0.755	Valid	0.756	Valid		
	<i>Y4.4</i>	0.764	Valid	0.764	Valid		
	<i>Y4.5</i>	0.878	Valid	0.878	Valid		

criterion, indicating adequate convergent validity, confirming that the indicators effectively represent each construct. Unlike the other construct, *Y2* is measured using a single indicator, resulting in the AVE value of 1.000, which should be interpreted differently from the AVE values of multi-item constructs.

To ascertain whether all constructs in the model differ from each other, a discriminant validity test was performed by paying attention to the value of cross loading (Table 11). The cross-loading values of the *X1*, *X2*, *Y1*, *Y2*, *Y3*, and *Y4* constructs have a correlation value between the indicator and the construct greater than the correlation of the indicators in other constructs. The results of the convergent validity and discriminant validity tests show consistent numbers, with all indicators declared valid. This indicates that the model used has a good fit and can distinguish between one construct and another.

Construct reliability test Construct reliability was evaluated using composite reliability (Table 12), for which the values achieved above the 0.70 threshold, indicating strong internal consistency. *Y2* has one indicator, resulting in a CR value of 1.000, which should be interpreted differently from the CR value of multi-item constructs.

Inner model test Model fit Model fit was assessed using the

Standardized Root Mean Square Residual (SRMR). According to Hair et al. (2022), SRMR values below 0.08 indicate a good fit, whereas values below 0.10 are considered acceptable. The SRMR values of the saturated model (0.103) and estimated model (0.110) were slightly above the recommended threshold, indicating a marginal but still reasonable fit between the proposed model and the observed data. Model evaluation was further supported by the assessment of construct reliability, validity, and the explanatory power of the structural model.

According to Hair et al. (2022), the model shows that the R^2 values *Y1*, *Y2*, and *Y3* are categorized as weak, while *Y4* is moderate (Table 13).

Significance test The direct path analysis revealed that some relationships were significant, while others were not (Table 14). The agroecological principle (*X1*) has no significant effect on agroforestry revenue (*Y1*). This indicates that the application of agroecological principles does not directly increase agroforestry revenue, likely working through indirect mechanisms, such as increased land productivity or ecological efficiency that subsequently affect income. Meanwhile, on non-agroforestry revenue (*Y2*), the agroecological principles (*X1*) also has no direct effect, possibly because sources of income outside agroforestry are more influenced by external factors such as labor market access

Table 11 Cross-loading in discriminant validity test

Indicator	<i>X1</i>	<i>X2</i>	<i>Y1</i>	<i>Y2</i>	<i>Y3</i>	<i>Y4</i>	Description
<i>X1.1</i>	0.753	0.378	0.122	0.010	0.160	0.519	Valid
<i>X1.2</i>	0.509	0.264	0.296	0.171	0.055	0.331	Valid
<i>X1.5</i>	0.705	0.333	0.184	0.028	0.130	0.418	Valid
<i>X1.6</i>	0.846	0.638	0.343	0.091	0.112	0.630	Valid
<i>X2.1</i>	0.556	0.785	0.357	0.126	0.271	0.594	Valid
<i>X2.3</i>	0.203	0.603	0.362	0.144	-0.114	0.316	Valid
<i>X2.5</i>	0.543	0.871	0.403	0.159	0.211	0.594	Valid
<i>Y1.1</i>	0.342	0.482	0.921	0.131	-0.012	0.412	Valid
<i>Y1.2</i>	0.145	0.221	0.596	0.022	-0.014	0.216	Valid
<i>Y2.1</i>	0.103	0.186	0.117	1.000	-0.030	0.144	Valid
<i>Y3.2</i>	0.230	0.121	-0.012	-0.043	0.809	0.243	Valid
<i>Y3.4</i>	0.045	0.199	-0.014	-0.008	0.849	0.274	Valid
<i>Y4.1</i>	0.561	0.548	0.378	0.150	0.265	0.851	Valid
<i>Y4.2</i>	0.246	0.286	0.095	0.014	0.504	0.530	Valid
<i>Y4.3</i>	0.606	0.470	0.260	0.127	0.201	0.756	Valid
<i>Y4.4</i>	0.496	0.561	0.325	0.129	0.126	0.764	Valid
<i>Y4.5</i>	0.634	0.666	0.486	0.106	0.164	0.878	Valid

Table 12 Composite reliability values in the model

Construct	Composite reliability	Description
Agroecological principles (<i>X1</i>)	0.801	Reliable
Livelihood resources (<i>X2</i>)	0.802	Reliable
Agroforestry revenue (<i>Y1</i>)	0.743	Reliable
Non-agroforestry revenue (<i>Y2</i>)	1.000	Reliable
Subjective well-being (<i>Y3</i>)	0.815	Reliable
Sustainability (<i>Y4</i>)	0.873	Reliable

Table 13 *R*-square values of dependent construct

Construct	<i>R</i> -square	<i>R</i> -square adjusted	Description
Agroforestry revenue (<i>Y1</i>)	0.241	0.236	Weak
Non-agroforestry revenue (<i>Y2</i>)	0.035	0.028	Weak
Subjective well-being (<i>Y3</i>)	0.001	-0.006	Weak
Sustainability (<i>Y4</i>)	0.622	0.616	Moderate

Table 14 Significance test outputs on direct effect model

Paths	Coefficient (β)	<i>t</i> -statistics	<i>p</i> -values	Description
<i>X1</i> → <i>Y1</i>	0.076	1.092	0.275	Insignificant
<i>X1</i> → <i>Y2</i>	-0.012	0.274	0.784	Insignificant
<i>X1</i> → <i>Y4</i>	0.413	10.480	0.000	Significant
<i>Y1</i> → <i>Y3</i>	-0.012	0.224	0.822	Insignificant
<i>Y1</i> → <i>Y4</i>	0.126	3.067	0.002	Significant
<i>X2</i> → <i>Y1</i>	0.441	8.626	0.000	Significant
<i>X2</i> → <i>Y2</i>	0.193	2.286	0.023	Significant
<i>X2</i> → <i>Y4</i>	0.328	7.224	0.000	Significant
<i>Y2</i> → <i>Y3</i>	-0.028	0.500	0.617	Insignificant
<i>Y2</i> → <i>Y4</i>	0.031	1.120	0.263	Insignificant
<i>Y3</i> → <i>Y4</i>	0.185	4.094	0.000	Significant

and non-agricultural business opportunities. On the other hand, the agroecological principles (*X1*) have a strong and significant effect on sustainability (*Y4*). These findings confirm that the higher the level of application of agroecological principles, the stronger the sustainability achievement in community forest management.

Agroforestry revenue (*Y1*) has no significant effect on subjective well-being (*Y3*). In this case, subjective well-being is not determined by economic aspects alone but rather

is shaped by socio-psychological dimensions such as life satisfaction and self-actualization that may be obtained from agroforestry practices themselves. On the other hand, agroforestry revenues (*Y1*) show a significant positive relationship with sustainability (*Y4*), indicating the economic role of agroforestry constitutes an important component in supporting sustainable community forest management.

Livelihood resources (*X2*) emerge as an important variable in the model. This variable has a positive and

significant effect on both agroforestry ($Y1$) and non-agroforestry ($Y2$) revenue. This shows that ownership and access to various forms of livelihood capital (whether natural, human, social, financial, or physical) may enhance the capacity of households to access economic opportunities. In addition, livelihood resources ($X2$) also have a positive and significant effect on sustainability ($Y4$), confirming that a strong asset base is the key foundation for sustainable community forest management.

In contrast, non-agroforestry revenue ($Y2$) did not show a significant direct effect on subjective well-being ($Y3$) or sustainability ($Y4$). Substantively, this indicates that sources of income outside agroforestry tend to be complementary and relatively small-scale, so their contribution to improving quality of life and sustainability is still limited. In fact, there are indications of trade-offs, where involvement in non-agroforestry activities can reduce the allocation of time and energy to agroforestry activities as well as the social life of the community.

Finally, subjective well-being ($Y3$) has been shown to have a positive and significant effect on sustainability ($Y4$). This shows that non-material dimensions such as life satisfaction, positive emotions, and sense of life meaning play a role as social energy that drives sustainable resource management practices. Thus, sustainability is not only supported by economic factors and resources but also by subjective well-being conditions that can strengthen collective motivation and social cohesion in agroforestry management within local institutions.

The indirect pathway analysis (Table 15) showed that the mediation mechanism in this model was selective and that there was only one pathway that was statistically significant. Livelihood resources ($X2$) Agroforestry revenue ($Y1$) Sustainability ($Y4$) ($\beta = 0.055$; $t = 2.891$; p -value = 0.004) (Table 15). The most prominent role is seen in the agroforestry revenue ($Y1$) as the main mediator in influencing sustainability ($Y4$). Livelihood resources ($X2$) not only have a direct effect on sustainability ($Y4$) but also work through increasing agroforestry revenue ($Y1$). This indicates the existence of partial mediation, in which both paths, direct and indirect, play an equal role. Substantively, these findings confirm that household capacity to manage and utilize various livelihood assets will be more effective in promoting sustainability when embodied in productive and

ecologically aligned agroforestry practices. Thus, agroforestry revenue is a key mediator linking the livelihood asset base to the sustainability achievements of community forests.

The mediation pathway involving non-agroforestry revenue ($Y2$) did not show a significant role, either in relation to subjective well-being ($Y3$) or sustainability ($Y4$). This indicates that non-agroforestry activities are not the main mechanism in improving the quality of life and sustainability of community forests. This activity primarily serves as a diversification strategy to mitigate vulnerability, but its impact remains relatively limited. This condition is understandable considering that the main orientation of people's livelihoods still relies on the coffee-based agroforestry system, so activities outside the sector are not the main support.

Meanwhile, subjective well-being ($Y3$) actually showed a negative relationship tendency in its role as a mediator, although it was not statistically significant. This indicates that improvements in the subjective well-being dimension may not necessarily strengthen the linkage between household income sources and the sustainability of community forests. Substantively, these findings may reflect the possibility that subjective well-being is shaped by a broader set of factors beyond economic outcomes, including social relationships, cultural values, sense of security, and personal life satisfaction, limiting its role as a pathway linking livelihood outcomes to sustainability.

Discussion

Integrative sustainability This study demonstrates that economic, ecological, and institutional strengths drive CF sustainability. Economic benefits arise from livelihood diversification and market access, ecological resilience from agroforestry and conservation practices, and institutional cohesion from local norms and values. Strengthening weaker dimensions (technological innovation, social participation, and regulatory consistency) can further position community forests as models for improving welfare while sustaining ecosystems (Paudel, 2019).

From a sustainability perspective, social dimensions such as participation, capacity, and legal literacy shape how communities manage resources sustainably. Participation

Table 15 Significance test outputs on indirect effect model

Paths	Coefficient (β)	t -statistics	p -values	Description
$X1 \rightarrow Y1 \rightarrow Y3$	-0.001	0.159	0.874	Insignificant
$X2 \rightarrow Y1 \rightarrow Y3$	-0.005	0.220	0.826	Insignificant
$X1 \rightarrow Y2 \rightarrow Y3$	0.000	0.112	0.911	Insignificant
$X2 \rightarrow Y2 \rightarrow Y3$	-0.005	0.517	0.605	Insignificant
$X1 \rightarrow Y1 \rightarrow Y4$	0.010	0.997	0.319	Insignificant
$X2 \rightarrow Y1 \rightarrow Y4$	0.055	2.891	0.004	Significant
$X1 \rightarrow Y2 \rightarrow Y4$	0.000	0.224	0.823	Insignificant
$X2 \rightarrow Y2 \rightarrow Y4$	0.006	0.875	0.382	Insignificant
$Y1 \rightarrow Y3 \rightarrow Y4$	-0.002	0.222	0.825	Insignificant
$Y2 \rightarrow Y3 \rightarrow Y4$	-0.005	0.486	0.627	Insignificant
$X1 \rightarrow Y1 \rightarrow Y3 \rightarrow Y4$	0.000	0.150	0.880	Insignificant
$X2 \rightarrow Y1 \rightarrow Y3 \rightarrow Y4$	-0.001	0.218	0.828	Insignificant
$X1 \rightarrow Y2 \rightarrow Y3 \rightarrow Y4$	0.000	0.107	0.915	Insignificant
$X2 \rightarrow Y2 \rightarrow Y3 \rightarrow Y4$	-0.001	0.506	0.613	Insignificant

and advocacy capacity reflect empowerment, enhancing community bargaining power and legitimacy in resource governance (Mensah, 2021). Social sustainability depends on communities' ability to articulate interests collectively and inclusively, following participatory approaches that redistribute power in decision-making (Zhang, 2022). Inclusive participation ensures that sustainability is not confined to formal involvement (Said & Misana, 2023).

Legal literacy strengthens the aspect of tenure security, because understanding of legal rights and processes is key to maintaining legal and de facto access to natural resources (Satmaidi, 2025). Without clear tenure security and adequate legal knowledge, communities are vulnerable to losing their right to governance. In this context, tenure insecurity is often an indicator of social vulnerability, which if left unresolved can undermine social cohesion and threaten long-term sustainability (Kim, 2018).

Furthermore, the ecological dimension serves as a pillar of sustainability, ensuring the long-term maintenance of ecosystem functionality. Biodiversity is an important element that contributes to the stability and productivity of agricultural systems, in accordance with the principles of agroecology (Vikas & Ranjan, 2024). A high biodiversity score is a positive indicator for sustainability because it shows resilience to environmental change (Erktan et al., 2024). Soil and water conservation also increases the carrying capacity of ecosystems, which is important for maintaining basic ecological functions (Castellini et al., 2021).

Agroecosystem resilience is closely related to the concept of socio-ecological resilience, namely the ability of the system to absorb disturbances and maintain its main functions. This resilience is essential for the system to withstand external pressures and adapt to the growing intensity of climate variability (Folke, 2006). The relatively low resilience score indicates that adaptation strategies in CF management need to be strengthened, especially with a community-based approach and local institutional capacity building.

Economic sustainability is vital, as it underpins material welfare and household adaptability. This study shows that livelihood diversification and market access are key to reducing rural economic vulnerability (Ma et al., 2024). Yet, without strengthened value chains, good market access still leaves farmers in a weak position within the global agro-industrial system, as smallholders often face exclusion and high transaction costs (Cavaye et al., 2016). Strengthening cooperatives and local economic institutions is thus essential to enhance farmers' bargaining power. However, economic sustainability remains fragile due to dependence on external inputs—fertilizers, pesticides, and coffee cuttings—which heightens exposure to price fluctuations and policy shifts, making such input-intensive farming economically and ecologically unsustainable.

In contrast, the agroecological approach encourages the use of local inputs such as green fertilizers, compost, and seed independence, as well as reducing dependence on external markets. This not only improves cost efficiency but also strengthens farmers' self-reliance and expands access to markets for high-value organic products (Sehgal & Batool, 2024). With production diversification and integration into

fair and short value chains, smallholders can achieve better economic stability and resilience to external pressures.

The findings on the technology dimension reaffirm the principle of appropriate technology (simple, low-cost, locally based, and developed through participatory and sustainable processes) (Patnaik & Bhowmick, 2022) while agroecological perspectives emphasize technologies that sustain ecosystems, enhance diversification, and strengthen food sovereignty) (Somashekar et al., 2024). The low technology-access score reflects the persistent rural digital divide caused by high costs, weak infrastructure, limited literacy, and inadequate extension services, underscoring the need for participatory, farmer-led extension models that promote trust and practical knowledge exchange (Tambo & Wünscher, 2018). The evidence also highlights weak endogenous innovation, even though community-driven innovations are inherently more sustainable; thus, building community-based innovation systems becomes crucial for improving competitiveness and ensuring socio-technological resilience in forest-farming communities.

The institutional dimension of CF management is assessed through three pillars according to Scott (2008). The regulative pillar scores high where organizational structures, formal documents (e.g., Articles of Association/Bylaws, Social Forestry Work Plan, and Annual Work Plan), and coordination with PFMUs are present, but low scores reveal weak documentation, succession mechanisms, and external coordination. Despite legal CF permits, written-rule institutionalization remains uneven and often leans on informal practices, leaving governance vulnerable—e.g., undocumented norms and weak procedures in forest farmer groups and CF cases (Widiyanto et al., 2025). The normative pillar is expressed through *musyawarah*, cooperation, and value-based compliance; strong performance reflects internalized collective values, while weaker scores signal fragile norm adherence—patterns consistent with collective-action theory and Indonesian cases of *gotong-royong* groups (Ostrom, 2000). The cultural-cognitive pillar shows high achievement where “forest-farmer” identity, agroforestry traditions, and customary dispute handling reinforce cohesion more effectively than formal mechanisms—seen in Indonesian agroforest/commoning practices that root management in local identity and shared meanings (Wijayanti et al., 2025).

Institutional strengths in the normative and cultural-cognitive pillars underscore social norms and local identity as foundations of sustainability, while regulatory weaknesses remain a key challenge. Limited understanding of formal procedures and weak coordination hinder resilience, affirming Ostrom's view that clear rules, oversight, and inclusive participation are vital for managing common resources. Institutions as “rules of the game” reduce uncertainty and conflict through trust and coordination with external actors. Strengthening regulatory capacity is therefore crucial to complement socio-cultural forces and enable adaptive, collaborative governance amid climate and market pressures.

The pathway to sustainability The sustainability model analysis proposes a synthesis of structural and psychosocial factors that determine the sustainability of CF, which

includes the four propositions: 1) Agroecological performance and access to livelihood resources are the main structural factors. Agroecological performance as the basis for sustainability while access to livelihood resources is a determinant of the economy and sustainability; 2) Agroforestry activities as a basis for household income as well as a determinant of sustainability are the main economic factors; 3) The achievement of subjective well-being that can strengthen motivation and participation in agroforestry activities is the main psychosocial factor of sustainability; and 4) Non-agroforestry revenues are a complementary factor for sustainability. Its smaller contribution makes it more appropriately positioned as a complement that helps sustain household resilience.

This proposition frames sustainability as a multi-dimensional product that is the output of dynamic interactions between the socio-ecological dimensions and the local economy. The agroecological principle has been proven to make the most significant contribution to sustainability. Diversification, nutrient efficiency, and conservation of natural resources are the foundation of agricultural systems that are not only productive but also resilient to climate change and market pressures (Rosset & Altieri, 2021; Tittonell et al., 2022). In the context of CF, this principle serves as a bridge between ecological preservation and the fulfillment of the community's economic needs. Agroecology also enables the integration of natural and human capital through the enhancement of local knowledge, social values, and collective practices that promote sustainability (Bezner-Kerr et al., 2022).

Livelihood resources contribute directly and indirectly to sustainability. These findings confirm that the existence of assets alone is not enough; these assets must be converted through production systems that suit the local context, such as agroforestry. A strong mediation between livelihood resources agroforestry revenue sustainability demonstrates the importance of asset-based management systems to generate sustainable benefits (Octavia et al., 2023). This aligns with Bilal et al. (2024), who demonstrate that agroforestry significantly enhances rural livelihoods by integrating ecological productivity with socioeconomic resilience, thereby reinforcing its role as a key driver of sustainability.

Agroforestry revenue contributes directly to sustainability and positively influences subjective well-being, though the effect is modest. Its value extends beyond economics, offering psychosocial benefits like life satisfaction, security, and a sense of purpose. In contrast, income from non-agroforestry activities has little impact on sustainability or well-being, suggesting it serves more as a short-term coping strategy than a long-term solution. Recent studies confirm these findings. Agroforestry adopters in Indonesia report significantly higher life satisfaction and happiness (Wijayanto et al., 2022). It also constitutes over 50% of household income in some regions, far exceeding non-agroforestry sources (Santosa et al., 2024), and strengthens household resilience to climate and economic shocks (Sudomo et al., 2023; Tega & Bojago, 2023). Subjective well-being plays an important role in promoting sustainability. Although its mediating effect is weak, its direct effect is significant, indicating that subjective well-

being should be viewed as a livelihood outcome rather than an intermediary mechanism. Non-material aspects such as contentment, happiness, and social engagement foster active participation and collective stewardship of forest resources, reinforcing the social dimensions of sustainability in CF.

This synthesis emphasizes the necessity of agroecological management strategies rooted in local assets and supported by adaptive and participatory institutions. Agroforestry support should address not only technical but also social and institutional dimensions to enhance its contribution to sustainability. The success of CF in improving material and socio-ecological well-being depends on effectively transforming livelihood capital into adaptive, ecology-based strategies.

Implications for community forest governance Finally, we offer strategic implications for CF governance at the micro and meso levels, emphasizing the need for collaborative and networked rather than sectoral approaches. At the micro level, we focus on household-based governance and forest farmer groups. 1) Optimization of agroforestry systems. Agroforestry is not only seen as an agricultural practice but also as a sustainable production system that combines ecological and economic functions. The agroforestry model based on coffee and intercropping, if developed with agroecological principles, has been proven to increase the economic and ecological resilience of farmers (Sudomo et al., 2023). 2) Strengthening livelihood capital. Farmers have to be strengthened their access to land, small capital, locality-based conservation technology, and local knowledge to build a resilient production capacity. As revealed by Pokharel et al. (2015), investment in livelihood assets is a prerequisite for the emergence of an effective livelihood strategy in the community's forestry system.

Furthermore, 3) Focus on results, not administrative instruments. Although subjective well-being is not significant as a mediator, its direct influence on sustainability is evident. Psychosocial dimensions such as distributive justice, sociocultural recognition, and life satisfaction should be viewed as livelihood outcomes rather than mere instruments. CF programs need to enhance community well-being through empowerment and meaningful participation, as emphasized in recent studies on justice, social relations, and well-being in social forestry (Martin et al., 2016; Meijaard et al., 2021).

At the meso level, governance should strengthen institutional roles and supra-village actors through key pathways identified in the findings. 1) CF program redesign must shift assistance for FMUs, social forestry officers, the Regional Forestry Office, and related agencies toward developing productive and sustainable agroforestry rather than mere administrative compliance. Legalization should be followed by capacity building to ensure legal access translates into real empowerment. 2) Financial and market infrastructure need enhancement through cooperatives, access to green financing, local funding sources, and value chains for coffee and intercropping that link livelihood capital to sustainability.

Additionally, 3) Multi-actor networking is critical for maximizing agroforestry potential through collaboration among state, private, NGO, and academic actors within an

integrated governance ecosystem. Household and FFG capacity building will be ineffective without meso-level facilitation. 4) Hybrid and network governance approaches should guide all strategies, as governance is increasingly shifting from hierarchical control to interdependent networks (Rhodes, 2017). In this model, the state agent acts as a facilitator who enables collaborative arenas for learning and innovation. FFGs evolve beyond administrative units into dynamic learning and production groups, while FMUs, local governments, universities, cooperatives, and markets serve as nodes strengthening the community agroforestry ecosystem.

Limitation The study limitation is that the non-agroforestry revenue is measured using one indicator. As a result, conventional internal consistency measures, such as AVE, CR, and cross-loading, are not informative for this construct. Therefore, interpretations of these variables should be made with caution, and future studies are recommended to employ multiple indicators and to address the locations with higher levels of livelihood diversity.

Another limitation is the relatively low explanatory power of the model (R^2) for non-agroforestry revenue and subjective well-being. This indicates that the model may not fully capture the important determinants of this construction. Subsequent studies should consider including additional variables, such as job opportunities, social networks, and psychological factors, to increase the model's explanatory capacity.

Conclusion

This study indicates that overall sustainability performs well, with economic, ecological, and institutional dimensions providing relative strength, while technological innovation and inclusive participation remain the weakest aspects. The analysis further shows that agroecological principles and livelihood resources are the most significant drivers of CF sustainability, with agroforestry revenue acting as an important mediator. On the contrary, non-agroforestry revenues did not contribute as mediators. It is more functioning primarily as a coping mechanism. Finally, subjective well-being directly enhances CF sustainability, underscoring the psychosocial dimension of resilience, but it does not mediate it.

Recommendation

These findings imply that sustaining CF requires more than administrative reforms or legal access. Networked governance strategies are needed to strengthen agroecological practices, improve access to and utilization of livelihood resources, and reinforce institutional arrangements that bridge formal rules with local norms and identities. In addition, targeted efforts are needed to expand appropriate technologies, foster inclusive participation—including women and marginalized groups—and build resilience against market and climate pressures. By aligning local capacities and connecting them to key agencies, community forestry can better fulfill its dual role of sustaining ecosystems and securing community livelihoods.

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