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Institutional Alignment and Perceived Conservation Outcomes in Social Forestry: Evidence from a Sloping Highland Landscape in West Java, Indonesia

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ABSTRACT

Social Forestry is a flagship tenure-reform policy in Indonesia that seeks to reconcile rural livelihood improvement with forest sustainability. Yet, in steep upland landscapes, it remains uncertain whether expanded access rights translate into conservation-oriented land management. This study investigates how socio-economic pressures, institutional arrangements, and ecological conditions shape soil and water conservation within a Social Forestry scheme in Giriawas, West Java. Using a qualitative-dominant mixed-methods design, data were collected through household interviews, field observations, stakeholder consultations, and institutional analysis. The analysis was guided by a Drivers–Perception–Practices–Outcomes framework and an institutional fit perspective. Findings indicate that although farmers generally recognise erosion risks, land-use decisions are still dominated by short-term economic imperatives, and horticultural production remains largely production-oriented. Conservation practices are applied inconsistently, reflecting weak integration of soil and water conservation into local governance, limited alignment of incentives, and modest institutional capacity. Importantly, the assessment of conservation outcomes is based on stakeholder perceptions

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and qualitative field observations rather than direct biophysical measurements. The study suggests that tenure security alone is insufficient to generate environmentally sustainable land management. Instead, the findings suggest that perceived conservation outcomes are more favourable where governance arrangements, incentive structures, extension support, and ecological conditions are more closely aligned. These findings contribute an exploratory, context-specific explanation of why Social Forestry may succeed in expanding access while still falling short in delivering conservation benefits in erosion-prone upland systems.

Keywords: Institutional Alignment; Institutional Fit; Social Forestry; Soil and Water Conservation; Upland Horticulture

1. Introduction

Social Forestry has been widely promoted in Indonesia as a strategy to improve rural livelihoods while enhancing forest sustainability through tenure reform [1,2]. Yet, whether improved access rights automatically translate into conservation-oriented land management remains insufficiently understood, particularly in ecologically sensitive upland landscapes. In principle, tenure security is expected to strengthen stewardship by giving local communities greater responsibility and incentives to manage land sustainably [3,4]. In practice, however, the environmental effects of tenure reform depend on how institutional arrangements interact with local socio-economic conditions and landscape characteristics [5,6].

Indonesia offers a particularly important case because Social Forestry is implemented across diverse ecological and institutional settings, including steep highland areas where land-use pressure and erosion risk are high [7,8]. Recent studies suggest that while Social Forestry may improve access to forest resources and generate short-term livelihood benefits, its conservation performance remains uneven [1,9,10]. This is especially evident in upland horticultural systems, where production-oriented land use, frequent tillage, and limited soil and water conservation practices may undermine ecological sustainability [11–15].

A growing body of literature on Social Forestry in Indonesia has identified several persistent gaps. First, many studies focus mainly on tenure reform and economic outcomes. At the same time, relatively little attention has been given to the integration of soil and water conservation within community-managed forest systems [1,6]. Second, empirical analyses linking farmers' socio-economic characteristics to conservation behaviour in sloping forest landscapes remain scarce, particularly in highland horticultural contexts [16,17]. Third, few studies adopt a multi-stakeholder perspective to examine how internal institutional factors and external pressures jointly shape land management strategies in Social Forestry areas [8,18]. These gaps are important because Social Forestry should be assessed not only in terms of livelihood improvement, but also in terms of long-term environmental sustainability [9,10].

This study examines land management practices in the Social Forestry area of Giriawas Village, Garut Regency, a highland landscape characterized by steep slopes and intensive horticultural cultivation. Specifically, the study aims to: (1) analyze the socio-economic characteristics of participating farmers; (2) explore stakeholder perceptions regarding soil and water conservation-oriented land management; and (3) formulate strategic directions for enhancing environmental sustainability using a structured SWOT (Strengths, Weaknesses, Opportunities and Threats) analytical framework [19,20]. Importantly, the assessment of conservation outcomes in this study is based on stakeholder perceptions and qualitative field observations, rather than direct biophysical measurements of erosion, runoff, or soil degradation.

The study is guided by the view that conservation performance in Social Forestry is shaped by the alignment between governance arrangements, economic incentives, ecological conditions, and farmer capacities [4,21]. Household-level factors such as age, education, income, and farming experience influence conservation adoption [16,22], while institutional performance is strongly affected by extension support, access to programs, and the functionality of Forest Farmer Groups [8,18]. In this sense, the study does not claim a general theory but offers a context-specific explanation of how governance dynamics may facilitate or constrain conservation in a fragile upland setting.

By integrating socio-economic analysis with institutional and ecological considerations, this research con-

tributes to the literature by illuminating how governance dynamics influence conservation performance within community-based forest management systems. The findings are expected to inform more effective Social Forestry design, particularly in landscapes where livelihood goals must be balanced with environmental protection [5,10].

2. Materials and Methods

2.1. Study Area

The study was conducted in Giriawas Village, Cikajang Sub-district, Garut Regency, West Java, Indonesia. The area represents a highland landscape located on the slopes of Mount Cikuray, characterized by steep terrain, high rainfall intensity, and intensive horticultural cultivation within a Social Forestry scheme. The site provides an appropriate empirical setting to examine interactions between institutional arrangements and ecological vulnerability within a forest-dependent social–ecological system [4] (**Figure 1**).

Highland agricultural systems on steep slopes are widely recognized as being particularly susceptible to erosion when soil conservation practices are limited [23]. Given the integration of short-cycle horticultural crops into forest landscapes, the area represents a critical case for assessing governance–ecology linkages under decentralised forest management [24]. Field research was conducted from November to December 2024.

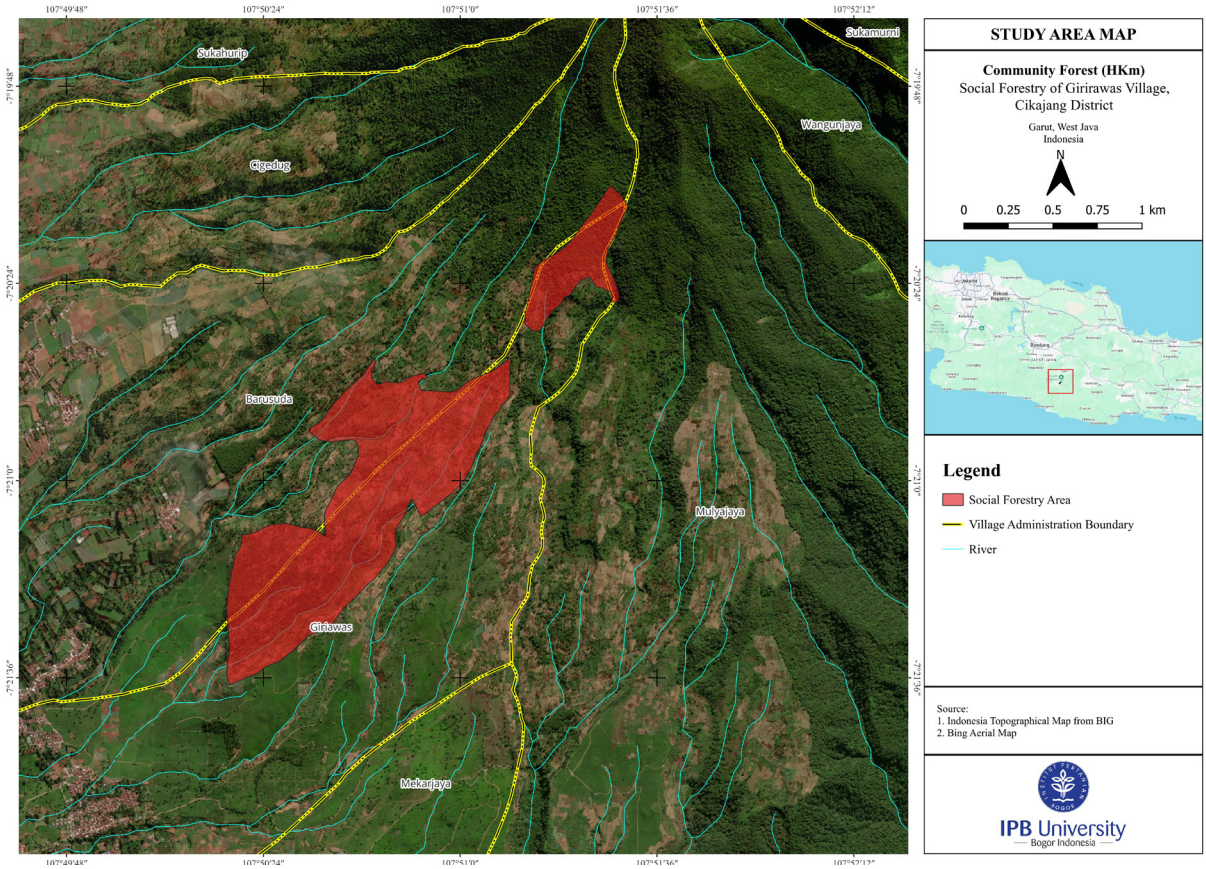

Figure 1. Research location in Giriawas Village, Garut Regency.
Source: 1. Indonesia topographical map from Badan Informasi Geospasial (BIG, Geospatial Information Agency). 2. Bing aerial map.

2.2. Research Design and Analytical Framework

This study adopts a qualitative-dominant mixed-methods design grounded in a social–ecological systems (SES) perspective. The SES framework emphasizes the interdependence between resource systems, governance arrangements, and user behavior [4]. Such an approach is particularly appropriate for community-based forest management contexts, where institutional performance and eco-

logical outcomes are mutually constituted [25].

The study integrates household-level socio-economic analysis, institutional assessment, and landscape ecological observation to understand drivers of conservation behavior. Mixed analytical designs are recommended when examining complex governance systems that involve both measurable characteristics and perception-based dimensions [26].

Rather than treating Social Forestry as a static policy intervention, this study conceptualizes it as a dynamic governance system shaped by institutional capacity, local incentives, and environmental constraints [27].

2.3. Operationalization of Key Variables

To ensure analytical coherence, key constructs derived from the conceptual framework were operationalized into measurable dimensions. The framework assumes that socio-economic, institutional, and biophysical factors jointly influence farmers' perceptions and conservation capacity. These perceptions subsequently shape land management practices, which in turn determine ecological and governance outcomes (**Figure 2**).

2.3.1. Socio-Economic Drivers

Household-level variables such as age, education, income, and farming experience were examined because socio-economic characteristics are known to influence adoption of conservation practices [16]. Education level and farming experience, in particular, have been found to shape environmental awareness and willingness to implement soil conservation measures.

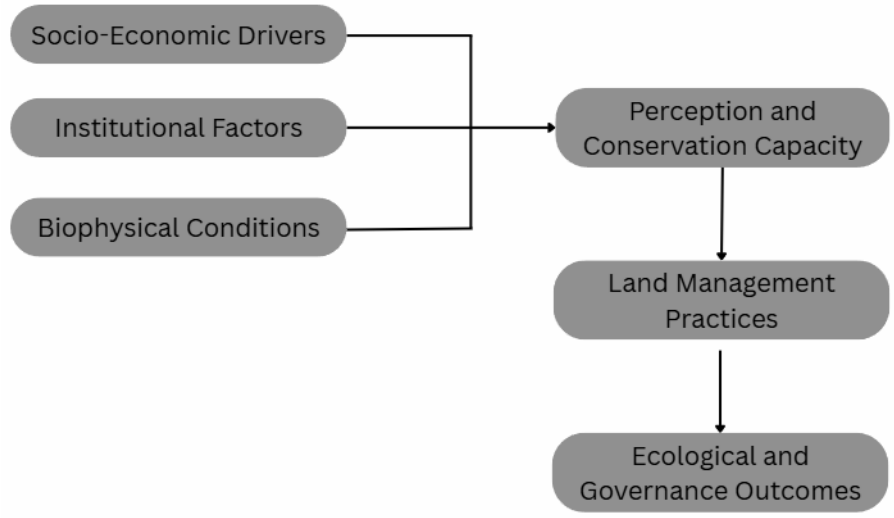

Figure 2. Conceptual Framework of Operational Variable.

2.3.2. Institutional Factors

Institutional variables included extension intensity, access to support programs, and the functionality of Forest Farmer Groups (KTH). Institutional performance is widely recognized as a determining factor in collective resource management outcomes [24,28]. The analysis therefore examined not only formal structures but also the perceived effectiveness of governance mechanisms.

2.3.3. Biophysical Conditions

Slope gradient, cropping patterns, and visible erosion indicators were assessed to contextualize land management decisions within ecological constraints. Soil erosion risk in tropical highlands is strongly mediated by slope and rainfall interaction, particularly under intensive horticultural cultivation [23].

2.3.4. Perception and Conservation Capacity

Farmers' awareness of erosion risk and willingness to adopt conservation measures were explored through semi-structured interviews. Perception plays a mediating role between structural drivers and environmental behavior, especially in smallholder systems [22]. Understanding risk perception is therefore critical for explaining adoption patterns.

2.3.5. Land Management Practices

Observed practices were categorized into monoculture horticulture, agroforestry, contour planting, vegetative cover, and structural conservation measures. Such classification aligns with land-use typologies commonly used in agroforestry and conservation research [29].

2.3.6. Ecological and Governance Outcomes

Ecological outcomes were inferred from reported erosion events, soil fertility perceptions, and land stability concerns. Governance sustainability was evaluated in relation to institutional resilience and long-term management viability [30].

2.4. Sampling Strategy

We used purposive sampling, and more specifically a homogeneous-sampling approach [31]. The aim was not to cover a wide range of people, but to look closely at one well-defined group of actors directly involved in managing land and applying land-management rules within the Giriawas Social Forestry scheme. Studying a narrow, similar group in depth suits this kind of case-based governance research better than spreading the sample thin across a broad population.

KTH Giri Purnama Alam is the Forest Farmer Group authorised to manage the area under Ministerial Decree SK.9442/MENLHK-PSKL/PKPS/PSL.0/9/2023. From its membership, we set three conditions for taking part: the person had to be an active member on the KTH register, hold a working plot inside the Social Forestry boundary, and grow horticultural crops as their main produce. Members who had not planted for two consecutive seasons were left out, since their situation no longer reflected active land management. Thirty members met these conditions and were interviewed.

We did not fix the number of interviews beforehand. Instead, we kept interviewing until we stopped hearing anything new. The point at which fresh interviews no longer added themes to the Drivers–Perception–Practices–Outcomes framework. This is what the literature calls thematic saturation. Studies that have tested saturation in similar, homogeneous samples usually find that the main themes are covered within roughly 9–24 interviews [32]; at 30, we were well past that range. A few of the later interviews served mainly as a check, confirming that the themes held steady across differences in age, schooling, and how long each farmer had worked the land.

We then spoke with eight more people to bring in views from other levels of governance [33]: one official from the Provincial Forestry Service Branch Office, Region V, West Java (CDK); the head of Giriawas Village; five residents who live next to the Social Forestry area but do not farm inside it; and one trader in the middle of the horticultural value chain who buys produce from the group. Altogether, the study draws on 38 interviews, each lasting between 45 and 90 min.

2.5. Data Collection

Three complementary techniques were employed to enhance triangulation [34].

2.5.1. Semi-Structured Interviews

Semi-structured interviews provided an avenue to investigate participants' perceptions, motivations, and institutional limitations while allowing consistency for analytical comparison [34]. The interview guide was organized around specific elements of the conceptual framework, namely drivers, perceptions, behaviours or use practices, and outcomes.

2.5.2. Field Observation

In-person field observations were conducted to substantiate reported behaviours and/or to observe observable indicators of environmental degradation. Observational techniques are critical when conducting research on environmental governance to mitigate the potential for bias due to self-reporting by participants [33].

2.5.3. Secondary Data Review

Policy documents, Social Forestry permits, and agricultural statistics were reviewed to provide context regarding local governance. The use of document review strengthens institutional research by placing local findings in relation to larger regulatory frameworks [35].

2.6. Data Analysis Procedures

2.6.1. Thematic Analysis

The interview transcripts were analyzed using established qualitative procedures and coded using thematic

analysis [36]. The coding categories were derived from the conceptual framework as well as from emergent patterns found in the transcripts. In order to ensure reliability, two researchers independently coded a random subset of eight transcripts (20% of the total) and then compared their coding results using both percentage agreement and Cohen's kappa. The percentage agreement was 87%, and the Cohen's kappa statistic was 0.82 (95% CI: 0.74–0.90), indicating that the coding was in very close agreement and that there was a very strong chance that the agreement was not due to chance. Disagreements were resolved through discussion, and the remaining transcripts were coded by the primary researcher using the established codebook.

2.6.2. Cross-Dimensional Analysis

Cross-analysis was conducted to examine interactions between socio-economic variables, institutional support, and conservation practices. Multi-dimensional governance analysis is recommended for SES-based research to avoid reductionist interpretation [4].

2.6.3. SWOT-Based Strategic Evaluation

In developing the multi-stakeholder findings, a structured SWOT framework was used to help organize the findings and provide strategic, relevant implications related to land management as it relates to the Social Forestry scheme. This SWOT analysis was performed through four sequential analytical steps to provide empirical grounding and theoretical coherence for the analysis after critiques of descriptive SWOT approaches were given [19].

First step, candidate SWOT factors were extracted inductively from the thematic coding of the interview transcript through the identification of internal factors (i.e., strengths and weaknesses) as conditions under the control or ability of farmer respondents and local institutional actors and external factors (i.e., opportunities and threats) as conditions that originate as a result of policy, market, or biophysical contexts beyond direct local control.

As a second step, each candidate SWOT factor was cross-validated against the six stakeholder categories (1) farmers respondents, (2) village government, (3) Provincial Forestry Service Branch Office, (4) local institutions including KTH leadership, (5) surrounding community members and (6) actors in the value chain, such that a candidate factor was retained in the SWOT matrix only if it was substantively corroborated by at least two stakeholder categories, thereby reducing the possibility of bias by a single actor [3].

The third step involved mapping each of the retained SWOT factors onto the institutional alignment framework's four dimensions adopted by this study: Tenure Security (TS), Institutional Capacity (IC), Economic Incentives (EI), and Ecological Sensitivity (ES). This action allowed the existing empirical SWOT factor inventory to be connected with the theoretical dimensions that would mediate conservation outcomes, thereby operationalizing the institutional alignment concept [28,30].

Fourth, strategic options were created from the usual SO/WO/ST/WT logic with regard to the specific SWOT factors upon which the strategies were based (i.e., the strategic options themselves). The priority order of the strategies was based not on the number of times the factors were mentioned but on the depth of the dimensional deficit identified within the alignment mapping; thus, the strategic options that addressed the dimensions experiencing the greatest disadvantage between positive factors (i.e., Strengths and Opportunities) and negative factors (i.e., Weaknesses and Threats) were prioritised as the most analytically significant.

2.7. Validity and Reliability

To enhance internal validity, methodological triangulation was applied across interviews, observation, and document analysis [34]. Cross-verification between stakeholder categories was conducted to reduce single-actor bias.

Although qualitative in orientation, systematic coding procedures and explicit conceptual alignment improve analytical transparency and theoretical robustness [26].

3. Results

3.1. Socio-Economic, Institutional, and Biophysical Drivers

3.1.1. Socio-Economic Characteristics of Farmers

Most Social Forestry participants in Giriawas Village were between 30 and 55 years old, had primarily completed primary or junior secondary education, and had been

engaged in farming for more than 10 years, mainly in horticultural production systems [16].

The data in **Table 1** are descriptive, and since we did not have a sufficiently large number of respondents (30) and a sufficient number of qualitative interviews with farmers, we were unable to conduct inferential statistical tests. Although the text below implies that the characteristics of farmers may have an impact on their conservation behaviours (e.g., the level of education is related to being aware of soil conservation practices), this is based on the qualitative data collected during the interviews and not on this table. In order to statistically validate these patterns, a larger and more representative sample would be needed; this would be an exploration for further research.

Table 1. Characteristics of land-use farmers.

No	Farmer Characteristics	Frequency	Percentage
	Age		
1	Young: ≤14 Years	0	0%
	Middle: 15–64 Years	27	90%
	Old: ≥65 Years	3	10%
	Total	**30**	**100%**
	Education Level		
2	Low: Elementary School	26	92%
	Medium: Junior High School	4	8%
	High: Senior High School and above	0	0%
	Total	**30**	**100%**
	Income Level		
3	Low: ≤IDR 1,500,000	22	74%
	Medium: IDR 1,500,000–3,000,000	7	23%
	High: ≥IDR 3,000,000	1	3%
	Total	**30**	**100%**
	Expenditure Level		
4	Low: ≤IDR 1,500,000	13	43%
	Medium: IDR 1,500,000–3,000,000	11	37%
	High: ≥IDR 3,000,000	6	20%
	Total	**30**	**100%**
	Length of Land Management		
5	New: ≤10 Years	11	37%
	Medium: 10–20 Years	11	37%
	Long: ≥20 Years	8	26%
	Total	**30**	**100%**

Source: Primary Data (2025).

As a result of this research, it is apparent that households are heavily dependent upon horticultural products that have short production cycles (e.g., cabbage, chili, and carrots). Market fluctuations cause households to experience fluctuations in household income, and as a result, they seek out and implement maximising production strategies. In smallholder production systems, short-term pressures are often placed upon farmers to maximise production, particularly in locations where risk management is weak [22].

These results confirm that the economic reliance of households on horticultural commodities produced by intensive agriculture is also a major structural influence on the land-use decisions made by farmers, with land-use decisions made on the basis of improving production, consistent with broader research about tropical agriculture in smallholder agriculture [37].

3.1.2. Institutional Context

The Forest Farmer Group (KTH) supports the issuance of a formally approved Social Forestry license to the farmers. Although tenure has been granted, limited institutional support exists to promote sustainable agricultural and forestry practices. This is similar to a wider pattern of forest tenure reform in that, as tenure rights are devolved, they do not necessarily have the appropriate level of financial or technical support building [3,38].

Extension services are irregular, focusing mostly on

crop productivity rather than creating sustainable agricultural and forestry practices through soil and water conservation. It appears that even though the KTH operates as an administrative authority, it does not appear to provide adequate ecological stewardship through governance. Governance theory states that, in order to assess a governance system's overall effectiveness, we need to consider not only the formal institutions of governance but also the enforcement capacity, incentives and collective norms [27,28].

From this viewpoint, it appears that the continuing existence of a part of the institutional gap as a result of tenure reform has provided an increase in access to land; however, it has not created a governance system that adequately integrates conservation norms as part of its governance.

3.1.3. Biophysical Conditions

The region has steep terrain with heavy amounts of precipitation, making it naturally vulnerable to erosion due to rainwater flowing downhill. Studies of tropical upland areas have repeatedly proven that the combination of steep slopes with high levels of rainfall will increase the amount of surface runoff and soil erosion during periods of high-intensity agricultural production [23].

When examining plots in this region, it was clear at the beginning of the planting season that few of the plots had vegetative cover; that is, there were very few plants growing on the soil surface. Additionally, multiple plots exhibited evidence of rill erosive features. It has been established that the lack of structural erosion control in steeper gradients can lead to more rapid rates of land degradation than similar sites that contain some form of structural erosion control [39].

Biophysical factors contribute to increased vulnerability of soils to erosional processes when these same soils have experienced high levels of disturbance as a result of agricultural activities.

3.2. Farmers' Perception and Conservation Capacity

Farmers living and working in areas that are at risk of erosion have differing points of view on the severity of soil degradation. Many of the farmers surveyed acknowledge that erosion happens when there are large amounts of rain; however, they tend to think of it as a seasonal issue, rather than something that will build up over many seasons. Research that has focused on farmers' perceptions of erosion indicates that just because a person knows about the existence of an erosion risk does not necessarily mean the person will change their behavior due to that risk unless there are economic consequences to the individual [22].

Farmers are generally not familiar with the formal methods of soil and water conservation, such as planting crops on the bank and using vegetation as a barrier. Farmers are generally not interested in soil and water conservation methods because of the potential loss of planting space and the added labor. Other smallholder farmers engaged in the study of soil and water conservation found that perceived opportunity costs also had an impact on whether or not farmers adopted conservation measures [16].

Risk perception appears to be modified based on how farmers perceive their income needs in the near future. Farmers who have completed more education and farmers who have farmed longer tend to have more understanding of the decline of soil fertility. Recent studies have similarly shown that farmers' knowledge, risk perceptions, farming experience, and farm characteristics play important roles in shaping their adaptive responses to environmental change [40].

Overall, the capacity of farmers to participate in conservation is diminished due to limited technical capabilities and low levels of institutional support, in addition to the perception of trade-offs between participating in conservation and generating short-term profits.

3.3. Land Management Practices

3.3.1. Dominance of Monoculture Horticulture

In most of the region, the predominant system of land management relies heavily on the use of monoculture horticultural crops with intensive tillage and a short rotation history. This leads to high soil exposure during land preparation and increases the risk of surface runoff. Compared to diversified agroforestry systems, monoculture systems established on sloping terrain have been shown to have lower stability of soil structural integrity and to have an increased risk of erosion [29].

There are instances of crop rotations taking place, but they are limited to short-cycle vegetable categories that do not allow for extended periods of recovery for the soil. Additionally, limited plant diversity and landscape heterogeneity may reduce the resilience of agricultural landscapes and their capacity to maintain ecosystem functions [41].

3.3.2. Limited Adoption of Conservation Practices

The implementation of conservation measures is inconsistent and very informal. A small percentage of farmers align planting rows with slope contours but do not follow an organized design. There is little integration of agroforestry and a very limited number of structural conservation measures.

Research on the factors influencing conservation adoption suggests that institutional facilitation and cooperative action are the primary drivers to maintain these measures over time [3,40]. Without the development of structured support mechanisms, conservation will remain primarily an individual practice rather than a group activity. The evidence indicates that there are currently no conservation practices that have been institutionalized within the governance framework associated with the management of the Social Forestry scheme.

3.4. Ecological and Governance Outcomes

3.4.1. Ecological Implications

The observation of eroded soil and its subsequent report reflect that the soil continues to degrade progressively over time. Many farmers in this area are experiencing diminished soil productivity in specific areas due to the increased use of fertilizer. Soil degradation has been established to be possibly the primary cause of nutrient depletion and decreased crop yield on upland sites in the Tropics [39].

The amount of soil lost as a result of surficial runoff during periods of heavy rain adds to the amount of sediment being moved downstream. While no significant landslides occurred within the duration of the reporting period, the combination of steep terrain and high agricultural production provides a clear indication that if these conditions continue, there will be an increase in ecological vulnerability [23].

This ecological condition can be classified, at this point in time, as moderately degraded; however, there is capacity for reversing the ecological degradation through improved governance support for the conservation of ecological resources.

3.4.2. Governance Performance and Sustainability Implications

From a governance standpoint, access rights and short-term income opportunities for the Social Forestry scheme have been improved. However, there is still a weakly institutionalized ecological sustainability component. Decentralized forest governance contexts show similar results where security of tenure improves welfare but does not guarantee environmental restoration [25,38].

Limited inclusion of conservation planning within KTH indicates potential misalignment between institutional objectives and ecological safeguards. Sustainability is based on adaptive governance systems that align incentives with knowledge and ecological feedback [4,30].

Long-term sustainability of the Social Forestry system will therefore be dependent on enhancing institutional capacity to incorporate soil and water conservation into collective management practices.

3.5. SWOT Synthesis and Strategic Mapping

After synthesizing all of the socio-economic, institutional, perceptual, and biophysical findings, twenty-three SWOT factors were validated across multiple stakeholders (**Table 2**). The strengths associated with formal tenure security and institutional infrastructure were relatively high, while limited extension intensity, weak conservation internalization in KTH, and an income-expenditure imbalance all constrained conservation investment, which are weaknesses. The supportive policy environment and latent value-chain capacity of BUMDes and KUPS are both indicators of a favourable opportunity for conservation investment, while ecological vulnerabilities (i.e., water scarcity and climate variability) and market pressures (i.e., price volatility) pose a threat.

Cross-stakeholder validation (**Table 3**) demonstrates that the two weakest conditions associated with limited conservation adoption (W3) and limited extension coverage (W5) achieved the highest degree of agreement between all stakeholder groups (i.e., four out of six). Likewise, both of the strongest conditions associated with

formal tenure security (S1) and pre-existing institutional infrastructure (S5) also experienced similarly high degrees of corroboration across all six stakeholder groups. Ultimately, these areas of stakeholder convergence demonstrate that the gap in institutional support is not simply a belief held exclusively by one stakeholder group but rather a common diagnosis among all three groups (farmers, government, and local institutions).

Table 2. SWOT Matrix of Social Forestry Governance in Giriawas.

Strengths (Internal–Positive)	Weaknesses (Internal–Negative)
S1. Formal tenure security through Social Forestry permit (SK.9442/MENLHK-PSKL/PKPS/PSL.0/9/2023), valid for 35 years with 5-year evaluation cycles. S2. Productive age structure among farmer-respondents (90% in the 15–64 age range), supporting physical capacity for adaptive land management. S3. Diverse commodity base across the village (horticultural crops, tea, coffee, perennial fruits) enables economic diversification beyond monoculture. S4. Cross-stakeholder recognition of land degradation, with farmers, the village government, the forestry agency, and the wider community all identifying soil-quality decline as a problem. S5. Pre-existing local institutional infrastructure: Forest Farmer Group (KTH Giri Purnama Alam), Combined Farmer Groups (Gapoktan), and Village-Owned Enterprises (BUMDes). S6. Expressed willingness among farmer-respondents to adopt agroforestry-based land management under appropriate institutional support.	W1. Low formal education attainment among farmer-respondents (92% primary school or below) constrains adoption of technical conservation knowledge. W2. Income-expenditure imbalance: 74% of farmer-respondents in the low-income bracket (≤IDR 1,500,000/month), while expenditure spans medium-to-high categories. W3. Limited adoption of contour planting, vegetative barriers, and structural conservation measures despite recognized erosion risk. W4. Continued reliance on chemical fertilizers and short-rotation monoculture practices on sloping terrain. W5. Low intensity and narrow scope of agricultural extension services, with productivity emphasis rather than conservation focus. W6. Weak internalization of soil and water conservation within KTH governance functions. W7. Budget and infrastructure constraints limit rehabilitation and conservation investment at the institutional level.
Opportunities (External–Positive)	**Threats (External–Negative)**
O1. Supportive national policy framework: Permen LHK No. 9/2021 on Social Forestry Management and Permen LHK No. 23/2021 on Forest and Land Rehabilitation. O2. Potential for agroforestry development integrating perennial commodities (coffee, avocado, durian) with existing horticultural systems. O3. Existing value-chain institutions (BUMDes, Forest Social Business Group/KUPS) capable of capturing post-harvest value addition. O4. Possible engagement with external partners (NGOs, private sector, academic institutions) for technical and financial support. O5. Biophysical suitability for high-value horticultural and perennial systems given the highland altitude and rainfall regime.	T1. Localized water scarcity affecting downstream community livelihoods, attributable in part to upstream land-cover degradation. T2. Persistent deforestation and unauthorized land conversion pressures within and adjacent to the Social Forestry area. T3. Climate variability and pest outbreaks reduce horticultural yields and increase production risk. T4. Volatile horticultural commodity prices that weaken capacity for long-term conservation investment. T5. Implementation gaps in government conservation programs, including irregular extension coverage and limited program continuity.

Source: Authors' synthesis based on cross-stakeholder interviews (n = 38) and field observation, November–December 2024.

Table 3. Cross-Stakeholder Validation Matrix.

Factor	P	PD	CDK	KL	MU	PU	Total
S1	✓	✓	✓	✓			4
S2	✓		✓				2
S3	✓	✓				✓	3
S4	✓	✓			✓		3
S5	✓	✓	✓	✓			4
S6	✓		✓	✓			3
W1	✓		✓				2
W2	✓		✓	✓			3
W3	✓		✓	✓	✓		4
W4	✓		✓	✓			3
W5	✓	✓	✓	✓			4
W6	✓		✓	✓			3
W7			✓	✓			2
O1		✓	✓	✓			3
O2	✓		✓	✓			3
O3		✓		✓		✓	3
O4		✓	✓	✓			3
O5	✓		✓			✓	3
T1	✓	✓			✓		3

Table 3. *Cont.*

Factor	P	PD	CDK	KL	MU	PU	Total
T2		✓	✓	✓			3
T3	✓		✓	✓		✓	4
T4	✓	✓				✓	3
T5		✓	✓	✓			3

Notes: P = Farmer-respondents; PD = Village Government; CDK = Provincial Forestry Service Branch Office; KL = Local Institutions (KTH leadership); MU = Surrounding Community Members; PU = Value-Chain Actors. ✓ indicates that the factor was substantively corroborated by the stakeholder category. "Total" reports the number of stakeholder categories corroborating each factor. Only factors with corroboration ≥2 are retained in the SWOT matrix.

In reviewing the fourteen SWOT factors, as they are distributed across the four dimensions of institutional alignment (**Table 4**), it can be seen that there is an asymmetrical distribution of the fourteen SWOT factors across the four dimensions. The Institutional Capacity dimension (IC) has a higher percentage of weak/threat factors—eight out of the thirteen IC-related factors are classified as either weak or a threat, as compared to the other three institutional dimensions (ES, TS, EI). The Ecological Sensitivity dimension (ES) has a similar distribution, with six out of the seven ES-related factors classified as either weak or a threat. In contrast, Tenure Security (TS) has almost all of its factors classified as either strengths or opportunities, and Economic Incentives (EI) has a mixed but primarily negative distribution of its factors.

Table 4. Mapping of SWOT Factors onto Institutional Alignment Dimension.

Factor	Tenure Security (TS)	Institutional Capacity (IC)	Economic Incentives (EI)	Ecological Sensitivity (ES)
S1	●			
S2		●		
S3			●	
S4		●		
S5		●		
S6		●		●
W1		●		
W2			●	
W3		●		●
W4				●
W5		●		
W6		●		
W7		●	●	
O1	●	●		
O2			●	●
O3			●	
O4		●		
O5				●
T1				●
T2		●		●
T3			●	●
T4			●	
T5		●		

Notes: ● indicates that the SWOT factor primarily relates to the corresponding institutional alignment dimension. A factor may relate to more than one dimension. The mapping is interpretive and derived from the theoretical framework adopted in this study. Aggregated, the mapping reveals dimensional deficits in Institutional Capacity (IC) and Ecological Sensitivity (ES), with Tenure Security (TS) and Economic Incentives (EI) showing less acute imbalance.

This mapping of SWOT factors across the four dimensions of institutional alignment reveals an uneven distribution of strengths and constraints. Tenure security is largely associated with strengths and opportunities, whereas institutional capacity and ecological sensitivity are dominated by weaknesses and threats. This pattern supports the study's main finding that the principal barriers to conservation outcomes in the Giriawas Social Forestry scheme are not related to tenure security itself but rather to limitations in institutional capacity and the integration of ecological

considerations into governance practices. Based on this assessment, the strategic options presented in **Table 5** were prioritized according to their potential to address these identified constraints. Strategies classified as SO and WO focus on strengthening institutional capacity, improving conservation support mechanisms, and integrating ecological considerations into local governance arrangements. In contrast, ST and WT strategies are intended to reduce the risks associated with ecological vulnerability and external pressures that may undermine long-term sustainability. This interpretation is consistent with recent studies showing that variations in Social Forestry performance across Indonesia are strongly influenced by differences in local institutional capacity and governance effectiveness [42].

Table 5. Strategic Options Derived from SWOT—Alignment Synthesis.

Internal / External	Strengths (S)	Weaknesses (W)
Opportunities (O)	SO1. Leverage existing tenure (S1) and the national policy framework (O1): at the next five-year permit evaluation under SK.9442/2023, CDK Region V and the KPH attach slope-based conservation conditionality to permit renewal, requiring contour planting or vegetative cover on plots above a defined gradient. SO2. Combine farmer willingness (S6) with biophysical suitability (O5) and agroforestry potential (O2): KTH Giri Purnama Alam designates selected degraded plots for agroforestry pilots integrating coffee, avocado, and durian, supplied through the existing government free-seedling scheme and enforced through the KTH chair's standing internal agroforestry rule. SO3. Channel local institutional capacity (S5) into value-chain institutions (O3): route agroforestry and horticultural output through KUPS and BUMDes for aggregation and grading, ring-fencing a share of the margin as a group conservation fund. SO4. Use cross-stakeholder recognition of degradation (S4) as the basis for external partnership engagement (O4): build on documented farmer willingness to engage one external technical partner (academic or agroforestry-program type) for co-delivered extension and monitoring.	WO1. Use the policy framework (O1) and external partnerships (O4) to close the extension gap (W5): embed soil and water conservation modules into CDK Region V's per-village extension schedule, delivered through KTH Giri Purnama Alam and the Gapoktan at a frequency matched to available extension capacity. Structure the partnership as a tripartite arrangement: CDK as extension authority under Permen LHK No. 9/2021, KTH and Gapoktan as the uptake channel, and one external technical partner (an academic institution through community service or MBKM schemes, or an agroforestry program operating in the district) supplying training not available internally. Couple training with a concrete incentive, namely priority access to subsidized inputs (W4) for plots adopting contour planting or vegetative cover. WO2. Mobilize value-chain channels (O3) to ease the income-expenditure imbalance (W2): use BUMDes and KUPS marketing to raise farm-gate prices through aggregation and grading, directing part of the price premium toward conservation inputs. WO3. Use policy mandates (O1) to address the weak conservation function of KTH (W6): amend KTH Giri Purnama Alam's internal rules, building on the chair's existing agroforestry mandate, to make conservation compliance a condition of membership, formalized by CDK within the Social Forestry Management Plan (Rencana Kelola PS). WO4. Pilot agroforestry transitions (O2) to reconcile limited conservation adoption (W3) with income concerns (W2): run result-demonstration transitions on selected degraded plots to show that conservation and income are complementary, tracked with simple indicators.
Threats (T)	ST1. Activate local institutions (S5) and cross-stakeholder recognition (S4) against deforestation (T2) and water-resource change (T1): establish KTH-based early-warning monitoring using three low-cost indicators (percentage vegetative cover, presence of contour terraces, visible erosion rills), reported each cropping cycle and link them to community water-scarcity reports. ST2. Diversify the commodity base (S3) to reduce exposure to price volatility (T4) and climate variability (T3): shift part of the system toward perennial commodities (coffee, tea, konyal) to buffer horticultural swings. ST3. Use farmer willingness (S6) and tenure clarity (S1) to buffer program implementation gaps (T5): annex self-enforced conservation commitments to the Social Forestry permit so they persist when government programs lapse.	WT1. Strengthen extension intensity (W5) against climate and pest pressure (T3) on vulnerable smallholders (W2): broaden extension content to include climate-adaptation and integrated pest management modules, not conservation alone. WT2. Establish institutional monitoring (addressing W6 and T5) to detect early ecological degradation signals (T1, T2): institutionalize the three-indicator monitoring within KTH rules. WT3. Develop price-buffering mechanisms to address the income-expenditure gap (W2) and price volatility (T4) together: cooperative aggregation through KUPS plus conditional input subsidies tied to conservation compliance.

Among these options, three are prioritized because they address the constraints most consistently evidenced in the data and rely on structures already in place rather than new institutions. WO1 and WT3 target the two problems most frequently cited among respondents—the extension gap and the fertilizer-cost burden—and operate through existing actors (CDK extension staff, KTH, Gapoktan, and KUPS). WO3 offers the lowest-cost institutional lever, since embedding conservation in KTH rules builds on the chair's existing agroforestry mandate. The remaining SO and ST options function as supporting measures that reinforce these three priorities

4. Discussion

4.1. Tenure Reform without Institutional Alignment

Results show that Social Forestry has improved security of tenure and has provided new job opportunities; however, there has not been much success with integrating conservation strategies. This finding parallels earlier research showing that formal rights do not automatically improve environmental outcomes [3,38].

From an institutional perspective, governance effectiveness depends on the alignment of rules, incentives, local capacities, and ecological conditions [28]. In Giriawas, tenure devolution occurred in an ecologically vulnerable horticultural landscape, yet conservation-oriented support mechanisms remained relatively weak. Extension services were reported to focus primarily on agricultural production, while support for soil and water conservation was comparatively limited. These findings suggest that tenure reform can successfully deliver socio-economic benefits, but environmental improvements are more likely when conservation objectives are embedded within local governance and support systems [10,18].

4.2. Economic Drivers and the Conservation Adoption Dilemma

The prevalence of monoculture horticulture in Giriawas indicates how economically driven short-term thinking impacts land use decisions. Because horticulture is the main source of income for these farmers, farm management is based on maximizing productivity and market returns. Perceptions gained from interviews showed that conservation measures were often thought of as being an additional labour requirement, taking away from the available land to grow products, and having no guaranteed economic outcome. Hence, under the circumstances, conservation practices appeared to be less favourable than other activities that provided quicker financial returns. The results support the conservation adoption literature and indicate that environmental practices are likely to be adopted when there is a visible economic benefit, there is reduced risk, and there is institutional support for implementation [16,22]. Accordingly, the findings indicate that local livelihood priorities need to be considered when developing and promoting conservation objectives. Conservation interventions must be tailored to account for these socioeconomic disparities rather than applying a one-size-fits-all policy.

4.3. Institutional Fit and Ecological Vulnerability

The term "institutional fit" refers to how well different types of governance work together with the ecological context of the area being managed [30]. In Giriawas, the steepness of the hills, large amounts of rain, and lots of horticultural production create environmental situations where conservation measures need to be specially designed. Recent research has also shown that governance effectiveness can be affected by the way local institutions work and the difficulty of implementing programs [43].

Given these findings, there was no systematic approach to differentiating the measures used for erosion control based on the slope of the land or level of environmental risk. In addition, there appears to be little or no conservation data available for any given type of physical feature, despite the fact that most interviewees reported being aware of the potential for soil erosion at different levels. Therefore, current management practices may not be an accurate reflection of the ecological characteristics of the landscape.

The data provided by the SWOT analysis supports this conclusion. The areas of Institutional Capacity and Ecological Sensitivity have the highest level of weaknesses and threats, according to estimated scores. Conversely, tenure security has the highest number of positive and opportunity-rated factors. Together, these findings suggest the primary challenges to conservation in Giriawas are related not just to access rights but more so to limitations in terms of institutional capacity and ecological conditions. Viewed through the lens of sustainability transitions, the transfer of land rights in Giriawas represents an incomplete transition; it secures economic access but lacks the institutional feedback loops required to foster long-term ecological resilience.

These findings not only affirm the absence of institutions but also highlight opportunities to enhance conservation functions through existing governance systems. Developing measures, such as implementing slope-based planning, developing operational guidelines that foster

conservation, and providing improved institutional support, could help better align governance objectives with local ecological conditions [28,30].

4.4. Social–Ecological Resilience and Feedback Loops

Environmental change affects the resilience of social-ecological systems through the capacity of governance to both acknowledge and react to it [4,30]. Though many of the interviewees in Giriawa raised concerns about the erosion of land and soil fertility, these worries were not represented consistently through conservation actions or changes in governance systems. A number of participants experienced low levels of environmental monitoring, inadequate technical assistance, and a lack of coordination among stakeholders. However, it was not clear how much influence ecological feedback had on management priorities. Although the evidence does not prove that environmental information will create long-lasting conservation challenges when not integrated into local governance systems, it does suggest that such challenges may occur.

4.5. Reframing Social Forestry Sustainability

The findings indicate that Social Forestry sustainability should be evaluated through a broader framework than tenure security and livelihood improvement alone. While these dimensions remain important, long-term sustainability also depends on the extent to which governance systems support conservation-oriented land management [44]. The Giriawas case demonstrates the importance of considering interactions among ecological conditions, institutional arrangements, economic incentives, and farmer decision-making processes. Rather than relying on a single indicator of success, future evaluations of Social Forestry programs could benefit from integrating ecological indicators such as soil conservation performance, vegetation cover, or watershed protection with conventional measures of access, participation, and income generation.

4.6. Governance and Policy Implications

Based on these findings, improving environmental outcomes in Social Forestry landscapes requires a prioritized implementation strategy that strengthens conservation integration within existing governance arrangements. The first and most immediate priority is to incorporate explicit conservation objectives into KTH operational guidelines and management plans, ensuring that soil and water conservation become a core management objective rather than a complementary activity. The second priority is to strengthen farmers' capacity through extension programs that provide balanced support for both agricultural productivity and conservation practices. Given that awareness of erosion risks alone did not consistently translate into conservation action, targeted technical assistance and field-based demonstrations are needed to facilitate adoption.

The third priority is the development of incentive mechanisms that reduce perceived trade-offs between production and conservation. These may include conservation-linked assistance programs, performance-based incentives, or ecosystem service payment schemes that reward sustainable land management practices. Evidence from Indonesia indicates that appropriately designed payment for ecosystem services schemes can encourage landholders to engage in biodiversity-friendly land management and improve conservation outcomes [45]. Recent research in Indonesia similarly emphasizes that mainstreaming ecosystem services requires stronger integration of ecological objectives into policy, planning, and incentive mechanisms rather than treating environmental benefits as separate from existing development priorities [46]. Finally, long-term sustainability requires the establishment of integrated monitoring systems that combine livelihood indicators with ecological indicators such as soil erosion control, vegetation cover, and watershed protection outcomes. Implementing these measures through existing Social Forestry institutions and support mechanisms is likely to be more feasible and cost-effective than creating new governance structures, while also strengthening the long-term sustainability of upland Social Forestry landscapes.

4.7. Theoretical Implications

The findings of this study indicate a need to explore different theories to better understand how Social Forestry governance, land management, and ecological stewardship interact in the context of community-based landscapes, as well as to develop new theoretical frameworks for future

research. Additionally, previous work in the social, economic, and environmental arenas suggests the possibility of using disparate theoretical models to help explain and understand the interrelationships between both parts of Social Forestry.

4.7.1. Rethinking the Tenure–Sustainability Assumption

The Giriawas case continues the discussion on how tenure reform relates to environmental sustainability. Secure tenure is an established basis for community-based forest management; however, it appears that tenure reform's effects are subject to larger governance and structural factors. The results indicate that there is a more integrated perspective in which environmental outcomes occur from interactions between tenure arrangements, institutional support, conservation incentives, and local management practices, rather than viewing tenure reform as an individual path to conservation success. This indicates that continued Social Forestry research needs to evaluate not only access rights but also the governance conditions that provide long-term sustainability outcomes. Recent evidence from Indonesia demonstrates that Social Forestry outcomes are highly contingent upon local institutions, power relations, and governance arrangements, and that tenure reform alone rarely guarantees livelihood improvements or conservation success [1,6,10]. Moreover, assessments of Social Forestry performance increasingly recognize the existence of trade-offs among social, economic, and environmental objectives [9].

4.7.2. Extending Conservation Adoption Theory to Governance Contexts

Conserving natural ecosystems has been extensively researched with regard to the individual-level decision-making components (including but not limited to perceived risk, profitability, and compatibility with the current farming system) surrounding the decision-making process of adopting various conservation treatments [16,22]. Our study results indicate that the previously described individual-level decision factors may be influenced by the broader institutional framework, including factors such as land use decision-making authority. In addition, the provision of technical assistance, knowledge sources, and financial incentives for conservation practices for farmers can vary widely between different governance systems of Social Forestry. While this information does not negate previous frameworks for conservation practice adoption, it extends them by illustrating that the conditions imposed by the governance framework can influence the support system used by farmers when determining their decisions related to adopting conservation practices. Thus, our findings emphasize that when assessing conservation practice adoption, consideration must take into account two aspects: the individual behaviour of producers in determining their adoption of conservation practices and the interactions between producers and the institutional framework of resources available to them for implementing conservation practices.

4.7.3. Institutional Fit in Ecologically Sensitive Landscapes

The concept of institutional fit has been employed to assess conservation-related challenges in Social Forestry landscapes [29,43]. Rather than focusing solely on the presence or absence of governance arrangements, this perspective emphasizes the extent to which institutional mechanisms align with local ecological conditions and management requirements. The Giriawas case illustrates a situation in which tenure reform and local governance structures were successfully established, yet conservation outcomes remained limited because conservation-oriented support mechanisms were not fully aligned with the needs of a sloping horticultural landscape. This finding suggests that effective Social Forestry governance requires not only secure tenure and local participation but also institutional arrangements that are responsive to specific ecological vulnerabilities. The concept of institutional fit therefore provides a useful framework for understanding variations in conservation outcomes across different Social Forestry contexts, particularly in environmentally sensitive upland areas.

4.7.4. Social–Ecological Resilience and Delayed Feedback

The Giriawas court case highlights the need to consider both "social-ecological resilience" and the lagged effects of environmental feedbacks when evaluating Social Forestry. The benefits that derive from secured tenure, active participation, and improved livelihoods from implementing Social Forestry step up fairly quickly to visible

impacts for these three elements. However, the ecological impacts of Social Forestry take much longer to become visible. Therefore, if there are no visible ecological conservation outcomes from a Social Forestry policy, it does not necessarily mean that the policy has been unsuccessful; it could mean that the ecological conservation outcomes depend on the gradual accumulation of conservation practices, the ongoing institutional support for the implementation of Social Forestry, and the long-term adaptation by land users to the implementation of Social Forestry. This means that Social Forestry evaluations need to have an extended time frame for monitoring and incorporate ecological indicators that will capture the slow, gradual changes to soil conservation, vegetation health, and resilience in upland agricultural landscapes where environmental responses are often significantly lagged behind the social and economic improvements to governance and livelihoods.

4.7.5. Toward an Institutional Alignment Framework for Sloping Social Forestry Landscapes

The results indicate that conservation outcomes in Social Forestry are not produced by any single factor but emerge from the interaction among tenure security, institutional capacity, economic incentives, and ecological conditions. The Giriawas case shows that these factors should not be assessed in isolation when judging the sustainability of a community-managed setting.

Figure 3 presents this logic as a conceptual framework. It situates the farmer-level Drivers, Perception, Practices, and Outcomes sequence used in the analysis within a higher-order alignment among institutional, behavioural, and ecological domains, and it depicts how:

1. **Institutional arrangements** (tenure security, institutional capacity, and governance mechanisms, identified through the SWOT analysis) set the enabling or constraining environment.
2. **Farmer participation and behavior** (shaped by socio-economic drivers, perceptions, and economic incentives) mediate the response to those arrangements.
3. **Ecological context** (slope, rainfall, and vulnerability to erosion) determines the urgency and the specific form that conservation must take.
4. **Conservation outcomes** emerge from the degree of alignment or misalignment among these elements.

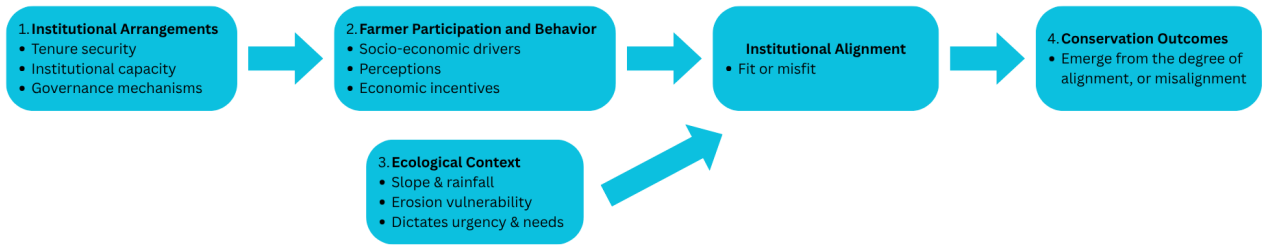

Figure 3. Conceptual framework for institutional alignment in sloping Social Forestry landscapes.

The framework is intended to be conceptual rather than a true statistical model. It is designed for a specific sloping upland setting, with its associations being interpretive in nature and based on data gathered from stakeholders' perceptions and field observations, rather than through direct biophysical data collection methods. Results indicate that secure tenure provides households with the ability to develop improved livelihood conditions. However, the degree to which these improved livelihood conditions lead to increased conservation will depend on the degree to which ecological conditions, institutional support, and governance are incorporated into local management systems. For practitioners, this suggests that sustainable resource management is more likely to occur when these multiple interrelated variables are addressed together rather than individually. To determine if the framework has more generalized applicability and to better understand the relationship between governance, conservation, and environment, comparative studies should be pursued across a range of Social Forestry applications.

4.7.6. Limitations and Future Research Directions

Three limitations deserve mention. First, our evidence is largely qualitative and perception-based. We cannot quantify the scale of soil loss or land degradation as a biophysical study would, and our ecological claims should be read with that in mind. Second, the work covers a single Social Forestry site, with farmer-respondents drawn purposively from one Forest Farmer Group; thematic saturation supports the analytical adequacy of the sample for the questions we asked here, but it does not license generalization to other Social Forestry settings, where ecological and institutional configurations may differ. Third, although institutional alignment functions as our central explanatory lens, we have not modelled the causal relationships formally. As explicitly stated in the limitations of this study, our evidence regarding conservation outcomes is largely qualitative and perception-based. We cannot mathematically quantify the precise scale of soil loss, water discharge alteration, or nutrient depletion as a rigorous biophysical study would, and our environmental assertions must be interpreted with these methodological boundaries in mind. Future work could measure biophysical factors, including erosion, soil quality, and vegetation cover, in combination with comparable designs across multiple sites to obtain a more rigorous test for causal inference and external validity than can be established using one qualitative case alone.

5. Conclusions

Based on the results of this study, no evidence was found that security of ownership (the right of farmers to access and use their land) was related to the implementation of soil and water conservation practices. Farmers are aware of the risk of erosion; however, they do not invest in soil and water conservation measures because they are unaware of their potential benefits. Importantly, the soil and water conservation outcomes evaluated in this study, both 'perceived' and 'reported,' are essentially based on stakeholder perceptions and qualitative observations rather than direct empirical biophysical measurements at the site level. The unevenness of conservation efforts is caused by differences in their ability and willingness to adopt sustainable farming techniques, stemming from size variability, the nature of their relationships with landowners, and varying levels of socioeconomic status.

Recommendations:

1. The Provincial Forestry Service Branch Office (CDK) should revise the Social Forestry Management Plan (Rencana Kelola PS) to include slope-based land use guidelines, with mandatory contour planting on plots above 25% gradient, to be reviewed at each five-year permit evaluation.
2. CDK should embed conservation modules into extension schedules delivered through KTH Giri Purnama Alam and Gapoktan, with a minimum frequency of two sessions per cropping cycle, and link training participation to priority access to subsidised inputs.
3. KTH should amend its internal rules to make conservation compliance a condition of membership, formalising the chair's existing agroforestry mandate and requiring at least 30% vegetative cover on all cultivated plots.
4. CDK and KPH should establish a low-cost monitoring system using three indicators (percent vegetative cover, presence of contour terraces, visible erosion rills), reported each cropping cycle through KTH, with results shared at village-level meetings to maintain accountability.

Author Contributions

Conceptualization, O.R., D.S., M.Y.G.F., B.W. and N.V.; data curation, D.S.; writing—original draft preparation, O.R. and D.S.; writing—review and editing, O.R.; supervision, O.R., M.Y.G.F., B.W. and N.V.; project administration, O.R. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used in this study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare no conflicts of interest.

AI Use Statement

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

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