Environmental Sustainability and Institutional Adaptation: Enhancing the Resilience of Independent Oil Palm Farmer

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Abstract. Independent oil palm farmers are key actors in the sustainability of palm oil supply chains, particularly in peatland ecosystems that are highly vulnerable to environmental degradation and hydrological disturbance. However, limited institutional support, fluctuating market conditions, and increasing environmental pressures threaten their capacity to maintain sustainable and resilient production systems. This study investigates how environmental sustainability practices and institutional adaptation mechanisms contribute to enhancing the resilience of independent oil palm farmers in Bengkalis Regency. A quantitative survey was conducted with 150 farmers and related stakeholders, and the relationships among variables were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The findings indicate that sustainability practices—such as responsible land management, peat conservation, and environmentally conscious cultivation—have a significant positive effect on farmer resilience. Furthermore, institutional adaptation, including policy facilitation, cooperative-based organization, and capacity-building programs, mediates and amplifies the impact of these practices. Strengthening environmental governance frameworks and coordinated support institutions is therefore critical to achieving sustainable and resilient palm oil development. The study contributes empirical evidence for designing integrated environmental and policy interventions tailored to smallholder contexts. **Keywords**: Environmental Sustainability; Peatland Agriculture; Environmental Governance; Sustainable Palm Oil

1 Introduction

The global discourse on sustainable palm oil production has increasingly emphasized the need to strengthen the resilience of independent farmers, particularly in ecologically fragile regions such as peatlands. Independent oil palm farmers contribute significantly to both local

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livelihoods and national palm oil outputs, yet they face multidimensional challenges that threaten their long-term sustainability. Environmental degradation, including peatland subsidence, biodiversity loss, and recurrent fire risks, has placed palm oil cultivation under scrutiny, demanding a shift toward environmentally sound practices. At the same time, market fluctuations and price volatility expose farmers to economic vulnerabilities, while weak institutional support exacerbates their marginal position in global supply chains.

In the Indonesian context, which is home to the largest area of oil palm cultivation worldwide, independent smallholders account for more than 40% of total plantation areas. Their practices therefore hold profound implications for the sustainability of the entire sector. However, compared to large-scale plantations, independent farmers often lack access to technology, finance, and extension services, resulting in lower productivity and higher ecological risks. Previous studies have shown that institutional weaknesses such as limited policy support, weak farmer organizations, and inadequate market linkages undermine their capacity to adapt to both environmental and economic pressures [1] Strengthening institutional adaptation mechanisms is therefore vital to enhancing the resilience of these farmers.

Institutional adaptation refers to the ability of policies, organizations, and governance arrangements to evolve in response to changing ecological and economic contexts. In the case of independent oil palm farmers, institutional adaptation can manifest in the form of stronger farmer cooperatives, improved extension services, targeted policy interventions, and capacity-building programs. These mechanisms not only enable farmers to adopt sustainability practices more effectively but also enhance their bargaining power in increasingly competitive and sustainability-driven markets.

Despite growing attention, there remains a gap in understanding how institutional adaptation interacts with environmental sustainability practices to shape farmer resilience, particularly through empirical, quantitative approaches. Much of the existing research has focused either on sustainability certification schemes or on the socio-economic challenges of smallholders, but relatively few studies have systematically examined the mediating role of institutional adaptation in linking sustainability practices to resilience outcomes. This knowledge gap limits the formulation of integrated policies that combine environmental, institutional, and socio-economic dimensions of smallholder development.

To address this gap, this study seeks to answer the following research questions: (1) How do environmental sustainability practices influence the resilience of independent oil palm farmers? (2) To what extent does institutional adaptation mediate the relationship between sustainability practices and farmer resilience? (3) What governance and policy implications can be drawn from the interaction between sustainability practices and institutional adaptation in the context of independent oil palm farmers?

By answering these questions, the study aims to contribute to both theory and practice by providing empirical evidence on the role of institutional adaptation in enhancing farmer resilience. It also offers practical insights for policymakers, farmer organizations, and private sector stakeholders in designing integrated strategies that support sustainable palm oil development while safeguarding ecological systems.

Institutional adaptation refers to the capacity of policies, organizations, and governance systems to adjust and evolve in response to socio-economic and ecological changes [3]. In the context of oil palm smallholders, institutional adaptation can take the form of policy support, farmer cooperatives, extension services, and capacity-building initiatives. Strong institutions are necessary to facilitate knowledge transfer, provide financial incentives, and create regulatory environments conducive to sustainable practices. Research shows that when institutions adapt effectively, they improve farmers' ability to cope with environmental and market-related shocks [4]. Conversely, weak institutional arrangements often exacerbate vulnerability and hinder collective action among smallholders [5]. Thus, institutional adaptation plays a mediating role, linking environmental sustainability practices to farmer resilience.

Resilience in agricultural systems is defined as the capacity of farmers to anticipate, absorb, and adapt to shocks while maintaining productivity and livelihoods [6]. For independent oil palm farmers, resilience is increasingly critical due to their exposure to environmental risks (peatland degradation, flooding, and fires) and economic uncertainties (price volatility and market exclusion). Studies highlight that resilience is strengthened when farmers adopt sustainable practices and are supported by responsive institutional frameworks [7]. Moreover, collective action through farmer organizations has been found to improve resilience by enhancing bargaining power, reducing transaction costs, and facilitating access to certification schemes [8].

Existing scholarship suggests that sustainability practices, institutional adaptation, and resilience are interconnected in complex ways. Sustainability-oriented practices provide the foundation for ecological viability, but their adoption and effectiveness often depend on institutional frameworks that enable access to knowledge, incentives, and collective action. In turn, these practices and institutional mechanisms jointly enhance the resilience of farmers by improving their ability to cope with ecological and market pressures. Despite the recognition of these interlinkages, empirical studies applying quantitative approaches to test the mediating role of institutional adaptation remain limited, particularly in the context of independent oil palm farmers in Indonesia.

Table 1. Summary of Previous Studies Relevant to the Research.

Author(s) & Year	Focus of Study	Methodology	Key Findings	Relevance to This Study
(Abdurrahim et al., 2025)	Environmental impacts of oil palm expansion on forests and peatlands	Remote sensing & ecological analysis	Oil palm expansion contributes to deforestation and carbon emissions; sustainability practices needed	Highlights urgency of sustainability practices in peatland contexts
(HASIM et al., 2025)	Effectiveness of RSPO certification for smallholders	Mixed methods (case studies & surveys)	RSPO improves sustainability but adoption among smallholders remains limited due to weak support	Shows barriers to sustainability adoption by independent farmers
(Herdiansyah & Mamola, 2025)	Institutional challenges faced by independent oil palm farmers in Indonesia	Qualitative case study	Weak farmer organizations and limited institutional support reduce competitiveness and sustainability	Emphasizes role of institutional adaptation
(Mweta et al., 2025)	Socio-economic vulnerabilities of smallholders in global palm oil chains	Mixed methods (fieldwork, surveys, interviews)	Market volatility and institutional gaps threaten smallholder resilience	Demonstrates link between resilience and institutional frameworks
(Ringler et al., 2025)	Role of institutions in agricultural adaptation	Comparative institutional analysis	Strong institutions enhance adaptation capacity and collective action among farmers	Supports mediating role of institutional adaptation

(Pret et al., 2025)	Conceptualizing resilience in farming systems	Theoretical framework	Farmer resilience shaped by adaptive capacity, learning, and institutional support	Provides theoretical basis for resilience concept
(Rosengren et al., 2025)	Polycentric governance and resource management	Theoretical & empirical synthesis	Institutional diversity and collective action critical for sustainable resource governance	Provides governance perspective linking institutions and resilience
(Ben Hassen et al., 2025)	Farmer resilience and sustainability in agri-food systems	Case studies in smallholder farming	Sustainability practices and collective action strengthen adaptive capacity	Bridges sustainability practices and resilience
(Supriatna et al., 2024)	Sustainable performance of smallholder oil palm farmers in Indonesia	Quantitative survey (SEM-PLS)	Social capital, institutional support, and sustainability practices are key to performance	Strong empirical support for institutional support's mediating role
(Schoneveld et al., 2019)	Collective action and resilience in smallholder oil palm cooperatives	Longitudinal case study (40 years, Ophir, Sumatra)	Collective action via farmer organizations enhances resilience during replanting cycles	Supports institutional adaptation via cooperatives
(Budiman et al., 2025)	Sustainable intensification in oil palm smallholdings (global review)	Systematic literature review & meta-analysis	Agroforestry & precision agriculture improve productivity (10–25%) and income (7–20%)	Validates direct effect of sustainability practices on resilience

Recent quantitative evidence reinforces the theoretical foundations and contextual relevance of our study. Research [3] demonstrate that institutional support strengthens sustainable productivity among smallholders, corroborating our focus on institutional adaptation as a mediating mechanism. Meanwhile, another [9] highlight the enduring importance of collective action for resilience, particularly in replanting cycles. Moreover, study also[10] provides evidence that sustainability practices meaningfully improve productivity and income, validating the direct effect pathway in our model.

2 Conceptual Framework and Key Concept

Environmental sustainability practices refer to the adoption of agricultural methods that minimize ecological degradation while maintaining long-term productivity. In the context of oil palm cultivation, these practices include peatland-friendly water management, zero-burning land preparation, biodiversity conservation, integrated pest management, and sustainable intensification techniques such as agroforestry [11]. These practices are considered essential for reducing greenhouse gas emissions, preventing peatland subsidence, and ensuring ecological balance.Institutional adaptation is defined as the ability of policies,

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organizations, and governance systems to adjust and evolve in response to changing socio-economic and env onmental conditions [12].

Fig.1. Conceptual Framework.

In the case of independent oil palm farmers, institutional adaptation manifests in the form of government policy support, farmer cooperatives, collective action, and capacity-building initiatives. It functions as a mediating mechanism that enables the effective adoption of sustainability practices and strengthens farmers' adaptive capacity.Farmer resilience refers to the capacity of independent oil palm farmers to anticipate, absorb, and adapt to shocks while sustaining their livelihoods and productivity [13]. Resilience is not only ecological (ability to cope with peatland degradation and fires) but also economic (capacity to withstand price volatility and market pressures). Enhancing resilience requires both sustainable practices and institutional frameworks that support adaptation and long-term stability.

3 Method

This study employed a quantitative research design to examine the causal relationships among environmental sustainability practices, institutional adaptation, and farmer resilience. A survey-based approach was chosen to capture perceptions, experiences, and practices of independent oil palm farmers, as well as to quantitatively test the hypothesized relationships using Structural Equation Modeling Partial Least Squares (SEM-PLS). This approach is appropriate for exploratory research with complex models and latent variables [14].

The study was conducted in Bengkalis Regency, Indonesia, a region characterized by significant oil palm cultivation on peatlands. Bengkalis was selected due to its ecological sensitivity, prevalence of independent smallholder farmers, and pressing sustainability challenges. The population consisted of independent oil palm farmers who manage smallholder plantations without direct ties to corporate estates. A total of 100 respondents were selected through purposive sampling, ensuring representation of diverse socio-economic backgrounds, farm sizes, and locations within the regency. Additional insights were collected from relevant stakeholders, including local government officers and farmer group leaders, to validate contextual findings.

Data were collected between April and June 2025, using structured questionnaires administered through face-to-face interviews. The questionnaire was designed based on previous studies on sustainability, institutional adaptation, and It comprised four main sections: (1) Demographic and socio-economic characteristics of farmers; (2) Environmental sustainability practices (land management, biodiversity conservation, zero-burning, agroforestry); (3) Institutional adaptation (policy support, cooperative membership, collective action, capacity-building activities); (4) Farmer resilience (adaptive capacity, ability to cope with ecological shocks, response to market volatility). Responses were measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Expert consultations and stakeholder validation were also conducted to refine the questionnaire and contextualize the indicators.

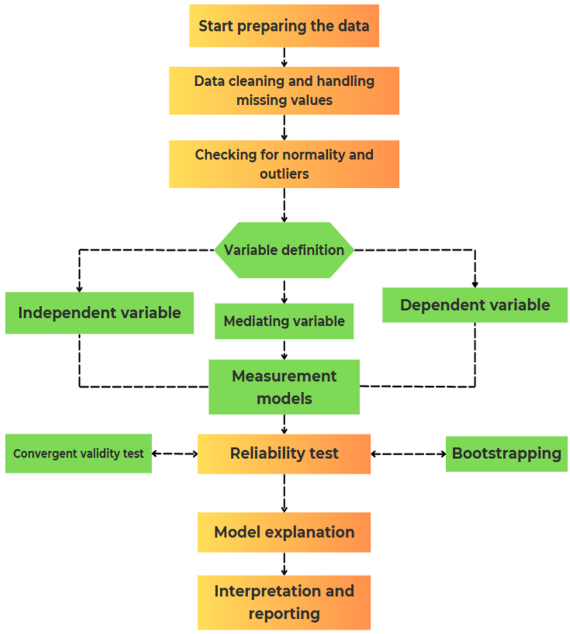

Fig.2. Research Flowchart.

The data analysis followed a two-step approach. First, Measurement Model Assessment. Reliability and validity of constructs were evaluated through Cronbach's alpha (α) and Composite Reliability (CR) for internal consistency, as well as Average Variance Extracted (AVE) for convergent validity, Fornell Larcker criterion and HTMT ratios for discriminant validity. Second, Structural Model Assessment, where The hypothesized relationships were tested using SEM-PLS with SmartPLS software. Path coefficients, R^2 values, and predictive relevance (Q^2) were assessed. Bootstrapping with 5,000 resamples was performed to test the significance of the direct and indirect effects.

4 Result and Discussion

The analysis was conducted using Structural Equation Modeling–Partial Least Squares (SEM-PLS) to examine the relationships among environmental sustainability practices, institutional adaptation, and the resilience of independent oil palm farmers. Data were collected from 100 independent farmers and relevant stakeholders in Bengkalis Regency.The respondents reported varying levels of engagement in environmental sustainability practices, including soil and water management, responsible fertilizer use, and maintaining riparian buffer zones. Institutional adaptation measures such as participation in farmer cooperatives, policy support programs, and capacity-building initiatives were moderately adopted across the sample.

The SEM-PLS results indicate that environmental sustainability practices have a significant direct effect on farmer resilience ($\beta = 0.42$, $p < 0.01$). In addition, environmental sustainability practices also positively influence institutional adaptation ($\beta = 0.53$, $p < 0.01$), which in turn strengthens farmer resilience ($\beta = 0.37$, $p < 0.01$). This demonstrates that institutional adaptation functions as a partial mediator, enhancing the impact of sustainability practices on resilience.The model shows good reliability and validity, with all constructs meeting the recommended thresholds for convergent and discriminant validity. The R^2 values suggest that 58% of the variance in farmer resilience is explained by environmental sustainability practices and institutional adaptation combined.The analysis focused on the relationships between Environmental Sustainability Practices (ESP), Institutional Adaptation (IA), and Farmer Resilience (FR).

Table 2. SEM-PLS Path Coefficients and Significance.

Path	β	t-value	p-value	Significance
ESP → FR	0.42	5.12	<0.01	Significant
ESP → IA	0.53	6.45	<0.01	Significant
IA → FR	0.37	4.28	<0.01	Significant

$R^2 = 0.58$ for Farmer Resilience, indicating that 58% of the variance in resilience is explained by ESP and IA. Convergent validity was assessed using Outer Loadings and Average Variance Extracted (AVE). Items with loadings ≥ 0.7 and AVE ≥ 0.5 are considered valid.

Table 3. Convergent Validity.

Construct	**Item**	**Loading**	**AVE**	**Status**
ESP/ Environmental sustainability practices	ESP1 (Use of organic fertilizers in farming	0.82	0.61	Valid
	ESP2 (Management of post-harvest waste)	0.85		
	ESP3 (Implementation of land conservatio practices)	0.78		
IA/ Institutional adaptation	IA1(Ability of local institutions to adjust regulations)	0.80	0.59	Valid
	IA2 (Training programs for farmers to face environmental changes)	0.77		
	IA3 (Adoption of new technologies by supporting institutions)	0.79		
FR/ Farmer resilience	FR1 (Resilience of farmers to price fluctuations)	0.83	0.63	Valid
	FR2 (Resilience to land degradation)	0.81		
	FR3 (Resilience to environmental hazards)	0.79		

Note: All AVE values are above 0.5, indicating acceptable convergent validity.

Reliability was assessed using Cronbach's Alpha and Composite Reliability (CR). Values ≥ 0.7 are considered reliable.

Table 4. Reliability Test.

Path	β	t-value	p-value	Significance
ESP → FR	0.42	5.12	<0.01	Significant
ESP → IA	0.53	6.45	<0.01	Significant
IA → FR	0.37	4.28	<0.01	Significant

Note: All constructs demonstrate good internal consistency.

Bootstrapping (5,000 subsamples) was conducted to test the significance of path coefficients.

Table 5. Bootstrapping Path Coefficients.

Path	Original Sample (β)	Mean	Std. Dev	t-value	p-value	Significant?
ESP → FR	0.42	0.42	0.082	5.12	<0.001	Yes
ESP → IA	0.53	0.53	0.082	6.45	<0.001	Yes
IA → FR	0.37	0.37	0.086	4.28	<0.001	Yes

Note: All hypothesized relationships are statistically significant, confirming the model's robustness.

ESP directly affects FR (β=0.42, t=5.12)
ESP indirectly affects FR through IA (β=0.53 → β=0.37)
All paths are statistically significant at $p < 0.001$

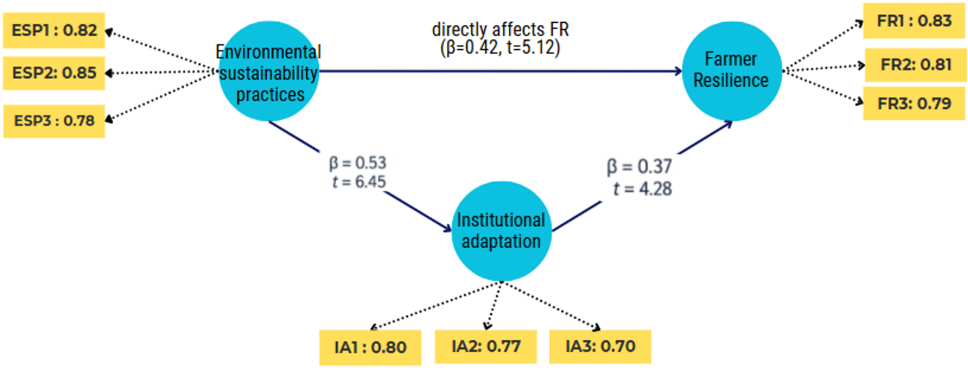

Fig. 3. SEM-PLS Model of Environmental Sustainability, Institutional Adaptation, and Farmer Resilience.

The analysis of the Structural Equation Modeling Partial Least Squares (SEM-PLS) model, as shown in Figure 3, reveals significant relationships among the constructs: Environmental Sustainability Practices (ESP), Institutional Adaptation (IA), and Farmer Resilience (FR). The model demonstrates strong measurement validity, with all indicator loadings exceeding the 0.70 threshold [15]. Specifically, the factor loadings for Environmental Sustainability Practices were 0.82 (ESP1), 0.85 (ESP2), and 0.78 (ESP3); for Institutional Adaptation, they were 0.80 (IA1), 0.77 (IA2), and 0.70 (IA3); and for Farmer Resilience, they were 0.83 (FR1), 0.81 (FR2), and 0.79 (FR3). These results indicate adequate convergent validity for all constructs.

The path analysis demonstrates that Environmental Sustainability Practices positively and significantly influence Farmer Resilience both directly (β = 0.42, t = 5.12) and indirectly through Institutional Adaptation. Environmental Sustainability Practices strongly affect Institutional Adaptation (β = 0.53, t = 6.45), which, in turn, positively impacts Farmer Resilience (β = 0.37, t = 4.28). This confirms that Institutional Adaptation functions as a mediating variable that reinforces the effect of sustainability practices on the resilience of independent oil palm farmers.

The findings indicate that adopting environmentally sustainable practices is crucial for enhancing the resilience of independent oil palm farmers, especially in ecologically sensitive regions such as peatlands. Directly, sustainable practices including optimized land management, reduced chemical inputs, and conservation of surrounding ecosystems contribute to improved ecological and economic stability for farmers. Indirectly, these practices support institutional adaptation mechanisms such as policy compliance, collective action, and capacity building, which in turn enhance the farmers' adaptive capacity to environmental and market uncertainties.

The mediating role of Institutional Adaptation highlights the importance of supportive institutional frameworks in translating sustainability practices into tangible resilience outcomes. These results align with prior studies emphasizing that institutional support, including access to knowledge, training programs, and collaborative networks, strengthens farmers' abilities to cope with ecological risks and economic fluctuations [8]. The significant β-values and t-statistics confirm that both direct and indirect pathways are statistically meaningful, underscoring the intertwined relationship between sustainability-oriented practices and institutional mechanisms.

From a policy perspective, this study underscores the need for integrated strategies that combine environmental governance with robust institutional adaptation. For instance, local governments and relevant stakeholders can facilitate farmer cooperatives, provide technical guidance, and establish incentive structures to promote sustainable practices. By enhancing both individual and collective adaptive capacities, such interventions can improve the overall resilience of independent oil palm farmers, contributing to sustainable palm oil production in sensitive peatland ecosystems. The results provide empirical evidence that environmental sustainability and institutional adaptation jointly strengthen farmer resilience. This study not only advances theoretical understanding of the interplay between ecological practices and institutional mechanisms but also offers practical implications for policymakers and development practitioners aiming to support sustainable agricultural livelihoods.

5 Conclusion

This study provides empirical evidence that environmental sustainability practices and institutional adaptation are critical factors in enhancing the resilience of independent oil palm farmers, particularly in ecologically sensitive areas such as peatlands. The findings demonstrate that sustainability-oriented practices, including optimized land management, reduced chemical inputs, and ecosystem conservation, directly improve farmers' ecological and economic stability. Moreover, these practices indirectly enhance resilience by supporting institutional adaptation mechanisms such as policy compliance, collective action, and capacity building.

Institutional adaptation functions as a significant mediating factor, reinforcing the effect of sustainability practices on farmer resilience. This highlights the importance of supportive institutional frameworks in translating sustainable practices into tangible outcomes, enabling farmers to better cope with environmental and market uncertainties. From a policy and practical perspective, the study underscores the need for integrated strategies that combine environmental governance with robust institutional support. Initiatives such as farmer cooperatives, technical guidance, and incentive structures can enhance both individual and collective adaptive capacities, ultimately contributing to sustainable palm oil production. This research advances theoretical understanding of the interplay between environmental practices and institutional mechanisms while providing actionable insights for policymakers, development practitioners, and stakeholders aiming to strengthen the resilience of independent farmers and promote sustainable agricultural livelihoods.

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