



Integrative framework for riparian buffer management for independent oil palm plantation

Maria Roswita Kartika Sari Bawono^{1,*}

¹ Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

*Correspondence: mariaroswita.ksb@gmail.com

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ABSTRACT

Background: Riparian buffers play a critical role in maintaining water quality, preventing erosion, and conserving biodiversity in oil palm landscapes. However, independent smallholders, who manage approximately 40% of Indonesia's oil palm plantation area, face constraints in riparian management due to limited land, capital, and technical capacity. Although riparian zones are legally protected, policy implementation remains weak. Meanwhile, the traditional local wisdom system in Jambi has demonstrated ecological and socio-economic benefits. This study aims to develop an integrative riparian management framework for independent oil palm smallholders in Jambi. **Methods:** This study employed a literature-based approach using national regulations, Best Management Practices (BMPs), and literature on riparian restoration and local customary practices. Data were analyzed through content analysis to identify key elements and develop an adaptive management framework. **Findings:** Formal regulations provide legal legitimacy for riparian protection but remain inadequately implemented. BMPs offer practical guidance, including buffer-zone delineation, native-species revegetation, and chemical-free management. The local wisdom system strengthens compliance through customary norms and shared community benefits. **Conclusion:** Adaptive co-management that integrates legal, technical, and local knowledge dimensions can strengthen social legitimacy and ecological resilience, supporting sustainable riparian management by independent oil palm smallholders. **Novelty/Originality of this article:** This study proposes an integrative riparian management framework that combines government regulations, technical management guidelines, and the local wisdom within an adaptive co-management approach, providing a socially legitimate and ecologically resilient strategy for sustainable riparian management.

KEYWORDS: independent smallholders; local wisdom; oil palm; riparian buffer.

1. Introduction

Riparian buffers are an essential component of ecosystems, including within oil palm plantation landscapes. According to the Regulation of the Ministry of Public Works and Housing No. 28/PRT/M/2015 on the Determination of Riverbank Boundaries and Lakeshore Boundaries, a riparian buffer is defined as the area along the left and right sides of a river, including artificial waterways such as canals, ditches, or irrigation channels. The primary function of a riparian buffer is to protect and maintain the ecological integrity of the river itself. The presence of vegetation in riparian areas is directly correlated with their ecological function, as riparian vegetation can create a cooler and more humid microclimate while providing critical habitat for local biodiversity (Williamson et al., 2021). Finkler et al. (2021) demonstrate that the long-term loss of riparian vegetation reduces river ecosystem metabolism and weakens the river's natural capacity to process nutrients. Vegetation strips,

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such as trees and shrubs growing along riverbanks, act as effective buffer zones that prevent soil erosion and reduce the entry of sediment particles into the water. This leads to lower turbidity and improved water quality. According to Martins et al. (2021), rivers bordered by intact riparian vegetation exhibit better water quality than unprotected rivers, particularly in terms of clarity and temperature stability. However, oil palm is not recommended for riparian areas because its shallow root system is less effective at stabilizing riverbanks, and its cultivation practices can increase fertilizer and pesticide runoff into water bodies. Luke et al. (2017) show that natural riparian forests are far more effective in maintaining riverine ecosystem conditions than oil palm riparian zones.

In Indonesia, oil palm plantations managed by independent smallholders account for approximately 40% (6.21 million hectares) of the total 15.34 million hectares of oil palm cultivation, making them a significant component of the sector (Supriatna et al., 2024). Nevertheless, smallholders frequently face constraints such as limited capital, inadequate technological access, and insufficient financial support, resulting in relatively low efficiency and productivity, as noted in agribusiness research findings (Sokoastri et al., 2019). These conditions often prompt smallholders to cultivate oil palm within riparian areas, which ecologically disrupts natural buffer functions such as erosion control and sediment reduction, consequently affecting water quality and intensifying environmental problems.

The Indonesian government has designated riparian buffer areas as protected zones through Undang-Undang No. 32/2009 and Government Regulation No. 38/2011. Further technical clarification is provided in PUPR Regulation No. 28/PRT/M/2015. Although a regulatory framework exists, its implementation at the smallholder level continues to face numerous challenges. On the other hand, Indigenous communities in Jambi have long practiced local ecological wisdom, such as *lubuk larangan*, which prohibits fishing in specific river sections during certain periods. This practice has proven effective in conserving aquatic resources and providing both social and economic benefits. Unlike government-imposed regulatory approaches, *lubuk larangan* originates from customary norms and collective agreements within the community, giving it strong social legitimacy (Lubis et al., 2019; Rindarjono et al., 2018). Therefore, to address the challenges of riparian management faced by independent smallholders, a management framework that integrates legal, technical, and socio-cultural dimensions is needed to ensure adaptive and locally appropriate implementation.

The management of riparian buffers in oil palm plantation areas is a critical issue that requires a comprehensive approach. It cannot be viewed from a single perspective but must integrate ecological theory, environmental governance, and local community knowledge. These three dimensions complement one another in efforts to maintain ecological functions while supporting the social and economic sustainability of communities around plantation landscapes. From an ecological perspective, vegetation along riverbanks, commonly referred to as riparian vegetation, plays a vital role. Riparian vegetation helps protect water quality, prevents erosion and landslides, and supports the natural ecological cycles of river systems (Naiman & Décamps, 1997; Williamson et al., 2021). However, these important functions are often lost when natural vegetation is replaced by cultivated crops such as oil palm. This land-cover transformation reduces the capacity of riparian zones to maintain ecosystem health, leading to declining water quality and reduced biodiversity (Luke et al., 2017).

Environmental management cannot rely solely on legal instruments, even though Law No. 26 of 2007 on Spatial Planning designates riparian zones as protected areas. Environmental governance theory states that effective management requires a combination of formal regulation, the involvement of non-governmental actors, and the social norms practiced within communities (Lemos & Agrawal, 2006). In reality, many cases show that formal regulations do not operate optimally. Nevertheless, local communities often possess cultural mechanisms that contribute to environmental conservation. One example is the practice of *lubuk larangan* in Jambi, in which communities designate specific parts of the river where fishing is prohibited for a certain period. These customary rules are not only

respected but also more strongly adhered to because they are based on local values and norms (Berkes, 2012; Lubis et al., 2019).

Beyond customary norms, technical approaches also offer practical guidance for environmental management in oil palm plantations. Best Management Practices (BMPs) provide concrete recommendations, such as replanting native species in riparian zones, maintaining buffer areas without chemical pesticides or fertilizers, and protecting natural vegetation strips (Barclay et al., 2017). These guidelines reflect the principles of sustainability, where scientific knowledge does not remain at the theoretical level but is applied according to field needs (Clark & Dickson, 2003). However, the effectiveness of technical guidelines strongly depends on community acceptance. In this context, social legitimacy theory emphasizes that a policy or practice will only succeed if it aligns with community values, norms, and beliefs (Suchman, 1995).

To address these complex challenges, the adaptive co-management approach becomes highly relevant. This approach integrates the concept of adaptive management, which emphasizes learning-based decision-making (Holling, 1978), with co-management, which involves collaborative governance among government actors, local communities, and private stakeholders (Berkes et al., 1991). Through this integration, adaptive co-management enables formal rules, technical guidelines, and customary norms to complement one another. Riparian buffer management can thus be implemented in a more adaptive, flexible, and socially attuned manner (Armitage et al., 2009; Plummer et al., 2012). Therefore, the integration of ecological theory, environmental governance, technical guidelines, and local wisdom within an adaptive co-management framework provides a strong foundation for riparian management in oil palm landscapes. This integrated approach not only maintains the ecological functions of river systems but also enhances community participation and strengthens the social legitimacy of management practices. Ultimately, such governance arrangements offer a strategic pathway toward environmental, economic, and social sustainability.

Research on riparian management in oil-palm landscapes has evolved from ecological perspectives to governance-oriented analyses. Previous studies have established the ecological importance of riparian vegetation, but most have focused on biophysical aspects and seldom incorporated socio-cultural dimensions related to smallholder involvement. Likewise, technical guidelines from institutions such as Barclay et al. (2017) and scientific studies on riparian buffer effectiveness (Luke et al., 2017) provide practical restoration guidance but often overlook limitations in local capacity, resource access, and social acceptance. Research by Susanti et al. (2021) on agroforestry adoption among independent smallholders further highlights barriers that hinder widescale implementation of riparian technical guidelines. The study finds that constraints extend beyond technical knowledge and access to extension services; monoculture oil palm systems remain economically more profitable than agroforestry or riparian-compliant practices. This creates a governance gap between formal guidelines and the realities faced by smallholders with limited economic and institutional capacity.

The socio-cultural dimensions of riparian management have also been explored, including studies on local practices such as *lubuk larangan*, which have proven effective in maintaining water resources and strengthening social cohesion (Berkes, 2012; Lubis et al., 2019; Rindarjono et al., 2018). However, these practices are not yet integrated with formal regulations or environmental governance instruments, limiting their broader applicability. Governance studies similarly highlight weaknesses in the implementation of formal regulations, especially among small-scale oil palm producers who often struggle with legitimacy and resource constraints (Lemos & Agrawal, 2006; Supriatna et al., 2024). Although the literature provides initial insights into adaptive co-management (Armitage et al., 2009; Plummer et al., 2012), its practical application in riparian buffer management within oil-palm landscapes particularly those involving independent smallholders has not been thoroughly examined. This reveals a multidimensional gap linking ecological, technical, socio-cultural, and governance aspects.

This study develops an integrative approach to riparian buffer management for independent oil palm smallholders. Beyond identifying ecological functions and technical guidelines, it emphasizes the incorporation of local knowledge, socio-economic capacity, and formal regulation into an adaptive co-management model. This approach is expected to bridge gaps between scientific knowledge, international sustainability standards, and on-the-ground realities. The study contributes to natural resource management literature by proposing a contextualized governance framework and offers practical insights for improving sustainability in oil palm landscapes through collaboration among communities, government, and international organizations. Accordingly, this research not only expands the theoretical foundation of riparian management but also provides applied solutions for empowering smallholders and enhancing environmental sustainability.

2. Methods

This study uses a qualitative approach using a systematic literature review (SLR). This approach was chosen because it allows the researcher to synthesize previous research findings in a systematic, critical, and comprehensive manner (Snyder, 2019). It is based on the understanding that riparian buffer management by independent oil palm smallholders is not merely a technical or ecological matter, but is also closely related to legal frameworks, field practices, and the socio-cultural values of local communities (Gunarso et al., 2013). Through a qualitative approach, the study aims not only to collect information but also to evaluate and integrate data from multiple disciplines, including ecology, law, and socio-cultural studies. As a case study, this research focuses on Jambi Province, one of the provinces in Sumatra. The selected province represents a region where communities are highly dependent on oil palm plantations. At the same time, the province possesses local wisdom that is regarded as an adaptive response to environmental challenges. This selection is expected to provide in-depth insights into how formal regulations, technical guidelines, and local ecological knowledge interact in real-world contexts.

The initial stage of the SLR involved formulating the following research questions: what ecological, legal, and socio-cultural indicators can identify gaps between formal regulations, technical practices, and local realities in riparian buffer management? how do formal regulations, technical guidelines, and local customary practices interact in influencing riparian buffer management by independent oil palm smallholders in Jambi? Based on these questions, the objectives of the study are to identify ecological, legal, and socio-cultural indicators explaining governance gaps in the field, and to analyze the interactions among formal regulations, technical guidelines, and local wisdom within the context of riparian buffer management. The second stage consisted of identifying scientific literature from both international and national databases using keywords such as riparian buffer, independent smallholders, oil palm, local wisdom, *lubuk larangan* Jambi, and management practices. The third stage involved screening, which included an initial relevance check of the retrieved scientific articles. The fourth stage assessed the eligibility of the articles based on criteria such as being peer-reviewed, published within the last ten years, and discussing ecological, legal, or socio-cultural aspects of riparian management. Data analysis was then conducted using thematic coding by categorizing the literature into three main themes: formal regulations, technical guidelines, and local wisdom.

This approach is expected to provide a comprehensive understanding of the dynamics of riparian buffer management by independent smallholders and to illustrate the real challenges they encounter. By integrating ecological, legal, and socio-cultural dimensions, the research aims to reveal governance indicators and gaps, while also capturing the lived experiences of local communities. Ultimately, this research approach seeks to produce findings that bridge academic knowledge, policy needs, and on-the-ground smallholder practices, thereby supporting the development of sustainable riparian governance in Jambi Province.

2.1 Data collection

Data collection for this study was conducted using a systematic literature review approach to obtain secondary data related to riparian buffer management by independent oil palm smallholders in Jambi Province. This process followed the guidelines developed by Snyder (2019), which emphasize the importance of structured searching, screening, and examination of literature sources to ensure validity, transparency, and replicability of research outcomes. The literature search was carried out using international databases such as Scopus and ScienceDirect, as well as national databases. The combination of keywords used included “riparian buffer,” “oil palm smallholders,” “best management practices,” “adaptive co-management,” and “Jambi.” The search was limited to publications in Indonesian and English issued within the last ten years to ensure relevance to current policy and management practices.

The collected data were then categorized into three main groups. The first category consisted of national regulations, including Law No. 32 of 2009 on Environmental Protection and Management, Government Regulation No. 38 of 2011 on Rivers (Articles 51–53), and the Ministry of Public Works and Housing Regulation No. 28/PRT/M/2015 on Riverbank and Lakeshore Boundaries. The second category consisted of technical guidelines for the palm oil sector issued by the Roundtable on Sustainable Palm Oil (RSPO), namely the RSPO Independent Smallholder Standard (RSPO, 2019) and the Best Management Practices for Riparian Reserves, which serve as technical references for applying sustainability principles in riparian areas. The third category comprised local socio-cultural data, including the practice of *lubuk larangan* in Jambi, obtained from academic publications and research reports, representing local wisdom in maintaining water quality and biodiversity along riparian zones.

Each document obtained was evaluated based on four eligibility criteria: authenticity of the source (peer-reviewed publication or official institutional document), geographical and contextual relevance to riparian conditions in Jambi, theoretical alignment with adaptive management concepts, and the contribution of the information to understanding local practices. Literature that met the criteria was recorded in a data extraction matrix to ensure consistency and traceability of information. This approach ensured that the data used were both scientifically credible and contextually relevant, thus capturing the interactions among formal policies, industry technical guidelines, and local wisdom in Jambi Province.

2.2 Methodology for analysis

Data analysis in this study was conducted using a descriptive qualitative approach combined with source triangulation techniques. This approach was selected to ensure the authenticity and depth of interpretation of various types of secondary data sourced from legal documents, technical guidelines, scientific publications, and research institute reports. To avoid analytical bias toward particular opinions or institutions, source triangulation was used to compare and validate information from different categories of documents.

The first step involved identifying and classifying the sources. All data were grouped based on their origin and characteristics, including national regulations such as Law No. 32 of 2009 and Government Regulation No. 38 of 2011, technical guidelines such as the RSPO Best Management Practices for Riparian Reserves, and local socio-cultural sources such as the *lubuk larangan* practice in Jambi. The second step involved cross-source comparison to evaluate alignment, discrepancies, and conceptual relationships across the different categories. While source triangulation validated the credibility of information, cross-source comparison explored the consistencies and divergences among previously validated sources. This process helped identify areas where formal policies, technical guidelines, and local practices converged or conflicted.

The third step involved interpretive synthesis, which is the process of integrating information from multiple sources to develop conceptual conclusions. Through these three stages, the analysis aims to demonstrate the dynamics of adaptive governance in riparian

buffer management by independent smallholders. One reason for applying these analytical stages is the need to understand riparian management both as a local social practice and as a normative framework. Conceptually, the identification and classification stages establish each source within its original context so that its meaning is not distorted by differing cultural, legal, or technical logics (Bowen, 2009).

This study seeks to interpret the relationships among formal regulations, technical guidelines, and community practices through cross-source comparison, highlighting how various actors and interests negotiate sustainability values (Patton, 2015). Interpretive synthesis, in contrast, involves critically integrating findings to build a robust understanding of collaboration and adaptation dynamics in environmental governance. Creswell (2014) notes that interpretation extends beyond empirical explanation; it seeks a deeper understanding of how governing principles are enacted through social experiences and institutional practices at the local level. Thus, the analytical method used not only ensures the credibility and depth of interpretation but also provides comprehensive insight into how regulations, practices, and technical guidelines interact. Through this process, the study identifies pressures emerging from the interplay between formal regulations, sustainability standards, and local socio-cultural values.

3. Results and Discussion

Appendix 1 presents the findings from eight scientific articles that examined the *lubuk larangan* system in jambi province and its surrounding regions. most studies note that *Lubuk larangan* protects river ecosystems by imposing temporary fishing bans in designated areas. This system not only preserves water quality and fish stocks but also generates income for local communities, as the fish harvest is allocated for social activities. Village authorities and customary leaders act as the primary decision-makers within this culturally grounded and participatory management approach.

However, the literature review reveals several weaknesses, including the absence of clear standards regarding the width of riparian buffers, non-scientific monitoring systems, and limited involvement in spatial planning policies or formal regulations. There are no legal instruments supporting enforcement, as sanctions remain based on moral and social norms. Despite these limitations, *lubuk larangan* has proven to be socially and ecologically effective and can serve as a model for community-based conservation at both local and national scales.

Table 1. Gaps and integration pathways among formal regulations, best management practices, and *lubuk larangan* for riparian buffer management

Aspect	<i>Lubuk larangan</i> (Local wisdom)	RSPO BMP 2017 – riparian reserves	UU No. 32/2009 – Environmental Protection and Management (PPLH)	UU No. 26/2007 – Spatial Planning & Government Regulation No. 38/2011	Gaps and integration directions
Purpose of Riparian Protection	Protect river ecosystems, maintain fish stocks, and prevent environmental degradation based on customary rules and seasonal fishing bans.	Protect ecological functions of riparian areas: maintain water quality, prevent erosion, and provide biodiversity corridors.	Ensure protection of ecosystem functions and environmental carrying capacity (Articles 3 and 44).	Protect the protective function of river areas and riparian buffers (Article 35).	Gap: <i>Lubuk larangan</i> focuses on biodiversity and local food security, whereas RSPO and national laws emphasize biophysical functions.

Management Approach	Customary and participatory (community determines no-fishing zones, harvest periods, and sanctions).	Best Management Practices based on risk management and scientific guidance; company-driven.	Eco-regional approach and public participation (Articles 63–65).	Formal spatial management based on national and regional spatial plans.	Integration direction: recognition of <i>lubuk larangan</i> as a community-based buffer zone in national policy. Gap: <i>Lubuk larangan</i> relies on socio-cultural norms, while RSPO and legal frameworks rely on administrative and technocratic systems.
					Integration direction: Harmonizing customary systems into local spatial planning and community co-management. Gap: No national legal framework formally recognizes <i>lubuk larangan</i> as a conservation unit.
					Integration direction: Designating <i>lubuk larangan</i> as a local protected ecosystem through regional regulations or official decrees. Gap: Criteria for <i>lubuk larangan</i> are
Legal Basis/Implementing Authority	Customary institutions and village government (<i>rio, ninik mamak</i>).	RSPO as a voluntary private-sector standard.	Central, provincial, and district governments (Article 63).	Government and regional spatial planning agencies (Articles 9–11).	
Criteria for Protected Zone /	Based on physical and ecological	Minimum 5–100 m depending on	Determined according to carrying	Minimum 100 m outside urban areas	

Riparian Width	characteristics of the river (≈50–300 m on both sides).	river width; natural vegetation required (RSPO BMP, 2017).	capacity and environmental function (Article 44).	(PP 38/2011 under Law 26/2007).	not quantitatively standardized. Integration direction: Harmonization with RSPO and national standards to establish ecologically recognized riparian boundaries. Gap: <i>Lubuk larangan</i> lacks formal monitoring and scientific data. Integration direction: Technical support from environmental agencies or universities for community-based environmental monitoring.
Monitoring and Rehabilitation	Conducted voluntarily by the community; non-systematic.	Periodic monitoring (vegetation, water quality, erosion); annual RSPO audits.	Environmental monitoring required under AMDAL and UKL-UPL (Articles 54–56).	Oversight of spatial utilization compliance (Article 69).	Gap: RSPO and legal mechanisms allow formal participation but often remain top-down; <i>Lubuk larangan</i> is highly participatory but informal. Integration direction: Establish co-management collaboration among customary communities, local government, and private actors.
Public Participation and Community Involvement	High during planning (customary deliberation), decreases during monitoring.	RSPO requires open public consultation, especially with affected communities.	Public rights to information, participation, and environmental justice (Article 65).	Public participation required in preparing spatial plans (Article 65).	

Law Enforcement and Sanctions	Customary sanctions (fines of rice, goats, coconuts; social exclusion).	Internal corporate enforcement; certification may be revoked for non-compliance.	Administrative, criminal, and civil sanctions (Articles 76–82).	Penalties for spatial planning violations (Articles 69–73).	Gap: <i>Lubuk larangan</i> relies solely on moral and social sanctions; not recognized in national legal systems. Integration direction: Formalization of customary sanctions within regional environmental enforcement mechanisms.
Funding / Rehabilitation	Annual fish harvest revenues and community contributions.	Company funding for riparian restoration (CSR or environmental obligations).	State and regional budgets (APBN/APBD), plus obligations of business actors (Article 43).	Development budgets and environmental funds.	Gap: <i>Lubuk larangan</i> receives minimal formal financial support. Integration direction: Integrating village-based funding (e.g., village green fund) with local CSR contributions.
Integration into Spatial Planning / Permitting	Regulated by village/customary institutions; partially included in district spatial plans (e.g., Bungo).	Must be integrated with AMDAL and landscape conservation planning.	Main instruments include SEA (KLHS) and AMDAL.	Spatial plans must include riparian protection zones (Article 35).	Gap: <i>Lubuk larangan</i> is not formally listed as a protected zone. Integration direction: Recognition of <i>lubuk larangan</i> in RTRW as a “Customary Protected Zone.”

This table 1 compares formal regulations, best management practices, and local wisdom. All three share the objective of protecting the ecological function of rivers and maintaining water quality, albeit through different approaches. *Lubuk larangan* emphasizes social and spiritual values, RSPO BMP adopts a technical and voluntary framework, while government regulations rely on binding regulatory mechanisms. Differences also emerge in technical aspects such as determining riparian width, monitoring systems, and enforcement

mechanisms. Unlike RSPO and formal regulations, *lubuk larangan* does not include quantitative standards or official monitoring systems. Therefore, the recommended integrative approach is to recognize it as a community-based buffer zone that can be harmonized with RSPO technical standards and the national legal framework.

Table 2. Forms of interaction and synergy among formal regulations, best management practices, and *lubuk larangan* in riparian buffer management

Level of rules/source of practices	Key characteristics	Forms of interaction with other levels	Impacts on independent smallholders	Identified gaps	Directions for ideal integration and synergy
National and Regional Formal Regulations (Law No. 32/2009 – Environmental Protection; Law No. 26/2007 – Spatial Planning; Government Regulation No. 38/2011)	Regulate the protection of ecological functions of riparian buffers and protected areas. Top-down approach; monitoring by local government. Determination of riparian buffer width at 100 m outside urban areas.	Provide the legal foundation for spatial planning (RTRW) and plantation licensing. Weak interaction with customary systems, as customary areas such as <i>Lubuk larangan</i> are not always acknowledged	Smallholders generally do not understand formal riparian boundaries. Many oil palm plots are located within riparian zones without environmental permits.	Weak dissemination and implementation at the site level. Absence of a formal mechanism recognizing customary areas within smallholder plantation permits.	Integration of <i>Lubuk larangan</i> into RTRW and village-level Strategic Environmental Assessments (KLHS). Village-based environmental certification programs and recognition of customary forests along rivers.
Technical Guidelines – RSPO BMP 2017 (Riparian Reserves)	Set technical standards for riparian widths of 5–100 m depending on river width. Encourage natural vegetation, water quality monitoring, and community participation. Voluntary in nature, applicable to RSPO members.	Provide technical reference for companies and smallholder groups seeking RSPO certification. Possess potential to adopt customary practices (such as <i>Lubuk larangan</i>) as evidence of conservation.	Some smallholder groups supported by NGOs/RSPO have begun adopting vegetative protection zones following BMP guidelines. However, implementation remains limited due to lack of knowledge and financial capacity.	No strong incentive mechanism for non-certified smallholders. No specific guidance for integrating local customary practices into BMP implementation.	Strengthening the RSPO Smallholder Standard by incorporating local wisdom such as <i>Lubuk larangan</i> . Developing adaptive technical guidelines aligned with customary law and local spatial planning (RTRW).
Local Wisdom – <i>Lubuk larangan</i>	Customary river conservation system based on prohibiting fishing in deep pool areas. Community-managed (village	Socially recognized by communities but not formally acknowledged in spatial planning (RTRW) or	Smallholders living near <i>Lubuk larangan</i> are more likely to respect riparian zones and avoid planting oil palm along riverbanks.	Lack of technical support (riparian vegetation, scientific monitoring). Not recognized in formal legal systems, making	Hybrid governance model: recognizing <i>Lubuk larangan</i> as a Riparian Conservation Zone within local

leaders, customary elders, youth groups).	plantation licensing. Substantively aligned with RSPO BMP regarding riparian protection.	Social norms and customary taboos effectively deter violations.	it vulnerable to displacement by oil palm expansion.	environmental policies. Collaboration among customary institutions, government, and RSPO for mapping and protecting riparian areas.
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Table 2 illustrates how formal regulations, best management practices, and local wisdom interact to influence the actions and riparian management practices of independent smallholders in Jambi. Formal regulations, technical guidelines, and customary practices interact with one another. Strong legal foundations for riparian protection are provided by formal instruments such as Law No. 32 of 2009 and Government Regulation No. 38 of 2011, which derives from Law No. 26 of 2007; however, their implementation remains largely ineffective. There is no effective monitoring mechanism at the village level, and most independent smallholders still operate without adequate oversight systems.

Preliminary findings indicate that *Lubuk larangan*, as a community-based river management system, is effective in protecting aquatic ecosystems. Its management approach primarily seasonal fishing prohibitions helps conserve fish populations while generating economic and social benefits for local residents. The system is managed participatively by customary institutions and village authorities, but it still lacks formal legal recognition and established technical standards. Compared with the RSPO BMP (2017) and formal regulations, *Lubuk larangan* shares similar ecological objectives but differs in its approach, emphasizing social and moral values rather than technocratic instruments. The gaps lie in aspects of legality, scientific monitoring, and spatial planning integration.

The research findings are based on three core principles that form an integrative framework for riparian zone management: formal regulation, best management practices, and local knowledge represented by the *Lubuk larangan* system. Although each of these dimensions contributes in a complementary manner, they also display several conceptual and practical differences. The subsequent analysis focuses on how these three variables interact in managing riparian zones among independent smallholders in Jambi Province, and how their integration can strengthen community-based environmental governance (Armitage, Berkes & Doubleday, 2007; Berkes, 2009).

3.1 Formal regulation (legal aspects)

Broadly, Law No. 32 of 2009 on Environmental Protection and Management (PPLH), Law No. 26 of 2007 on Spatial Planning, Government Regulation No. 38 of 2011 on Rivers, and Ministry of Public Works Regulation No. 28/PRT/M/2015 on Riparian Boundaries constitute the main legal frameworks governing riparian zone management in Indonesia. Maintaining the ecological functions of rivers, safeguarding water quality, and preventing environmental degradation are the primary goals (Law No. 32/2009). However, the effectiveness of formal regulations remains limited, particularly among independent oil palm smallholders. Insufficient enforcement and the absence of economic incentives for smallholders to comply with the rules are major barriers (Simorangkir et al., 2019). Additionally, most independent smallholders have limited understanding of the boundaries and functions of riparian zones as defined by formal policy. Cross-sectoral coordination between local governments, plantation agencies, and environmental authorities is also lacking, which often results in policies remaining at the administrative level with minimal tangible outcomes in the field (Colchester et al., 2011).

There is also a lack of legal recognition of local practices, such as *Lubuk larangan*, within national conservation and spatial planning systems. Yet these local values should

form part of community-based protection strategies, particularly when aligned with the concepts of ecoregions and public participation as outlined in Articles 63–65 of the PPLH Law (Ostrom, 2010). Formal regulation therefore needs to move toward a co-regulation model in which government policies recognize and provide legal space for local initiatives to protect riparian areas (Berkes, 2009).

3.2 Best management practices

The Roundtable on Sustainable Palm Oil (RSPO), through the Best Management Practices for Riparian Reserves (2017) and the Independent Smallholder Standard (2019), provides technical guidelines for restoring and managing riparian zones sustainably. These guidelines establish buffer zones based on river width, the planting of native vegetation, the prohibition of fertilizers and pesticides within riparian areas, and participatory monitoring (RSPO, 2017). Based on the analysis, BMPs offer technically strong ecological standards that can be applied by independent smallholders (Carlson et al., 2018). However, implementation challenges remain. Due to financial constraints, limited labor, and restricted access to technical knowledge, many smallholders cannot fully comply with RSPO's technical guidelines. Many smallholders in Jambi still depend on oil palm monoculture systems, making BMP adoption economically unattractive (Jelsma et al., 2019).

RSPO's BMPs are designed as general global guidelines, which may result in discrepancies in strictness compared with national regulations. For instance, riparian width guidelines are not necessarily stricter than Indonesia's formal regulations, which specify binding national standards. Nevertheless, BMPs complement national regulations for rivers whose riparian boundaries have not yet been formally designated. Furthermore, BMPs are applied voluntarily, relying heavily on the willingness and awareness of individuals or farmer groups rather than enforceable legal mechanisms (RSPO, 2019). This results in a gap between the socio-economic realities of smallholders and the technical idealism of the guidelines. In this context, integrating local knowledge is essential. For example, BMP elements such as local-species revegetation can be aligned with traditional norms, such as prohibitions on tree felling or bathing in certain areas (Van Noordwijk et al., 2020). Such methods can facilitate community acceptance of modern environmental management principles.

3.3 Local knowledge: *Lubuk larangan*

Lubuk larangan is a traditional ecological knowledge system in Jambi that protects river ecosystems by prohibiting fishing in designated areas. Analysis of eight publications shows that this system is effective both ecologically and socially. It improves fish stocks, maintains water resources, and strengthens social cohesion at the village level (Saharjo & Setyawati, 2019). Fish harvests after the closed-fishing period are usually allocated to community activities such as building public facilities or funding religious events, and management is carried out participatively by village authorities and customary institutions (Nurdin et al., 2021).

Because it is grounded in customary norms and spiritual values, social legitimacy and community compliance are its major strengths. The weaknesses lie in the absence of scientific standards and formal legal foundations. For example, riparian width and environmental monitoring methods are not consistently defined. Instead of formal penalties, violations are subject to moral and social sanctions. Consequently, *Lubuk larangan* has strong potential to be incorporated into official conservation policies as a form of community-based conservation area or community-based buffer zone (Berkes, 2009; Armitage et al., 2007). Previous research on riparian management in oil palm landscapes has largely emphasized riparian vegetation for maintaining environmental quality. Studies by Luke et al. (2017) and Wilkinson et al. (2021) discuss the potential of natural vegetation to reduce erosion, improve water quality, and sustain ecosystem balance. However, most of

these studies have been conducted in the context of company-managed plantations, where management is supervised by government authorities under formal regulations. The socio-economic conditions of independent smallholders, who play a central role in this context, remain insufficiently addressed.

Most earlier studies are biophysical and technocratic in nature, focusing on ecological parameters without considering local social, economic, and cultural dynamics. As a result, policies and technical guidelines often appear impractical for smallholders with limited resources. For example, studies based on RSPO's BMPs (2017) and Carlson et al. (2018) provide technical guidance on riparian width, vegetation types, and chemical restrictions. Yet implementation remains limited among independent smallholders due to financial barriers, limited technical knowledge, and insufficient institutional support (Supriatna et al., 2024). Conversely, socio-cultural studies such as Berkes (2012), Lubis et al. (2019), and Rindarjono et al. (2018) demonstrate that *Lubuk larangan* functions effectively in maintaining aquatic ecosystem sustainability. Based on social norms and customary sanctions, the system regulates fishing bans in specific areas for defined periods. However, these studies primarily describe customary values without linking them to formal policies or technical guidelines. Nevertheless, the prohibition system can serve as a starting point for developing community-based environmental governance aligned with government policy and industry standards.

By proposing an integrative model of riparian zone management for independent smallholders in Jambi, this research fills that gap. Three major governance sources form its foundation: (1) formal regulations such as Law No. 32/2009 on Environmental Protection and Law No. 38/2011 on Rivers; (2) RSPO's technical guidelines (2017), which offer ecological and operational foundations; and (3) local knowledge embedded in the *Lubuk larangan* system as a moral and social basis. This approach is rooted in adaptive co-management, an approach emphasizing flexibility, stakeholder participation, and shared learning (Armitage et al., 2009; Plummer et al., 2012). This model transforms independent smallholders from policy recipients into active actors who shape riparian management strategies within their landscapes.

Table 3. Comparison between this study and previous research

Aspect	Previous Studies	This Study	Gap
Research Object	Focus on biophysical conservation at industrial and large-company scales (Luke et al., 2017; Williamson et al., 2021).	Independent oil palm smallholders in Jambi Province as the primary actors of riparian zone governance.	Limited research placing smallholders as the main focus and active managers.
Approach	Top-down approaches based on regulations or technical guidelines (RSPO, 2017; Carlson et al., 2018; Supriatna et al., 2024).	Adaptive co-management approach that integrates local knowledge of <i>lubuk larangan</i> , formal regulations, and RSPO technical guidelines (Armitage et al., 2009; Plummer et al., 2012; Lubis et al., 2019).	Lack of cross-dimensional integration among ecological, legal, and socio-cultural elements; this study therefore adopts a community-based collaborative approach.

The table above shows that previous studies tend to view riparian zone management as an administrative or technical task, where success is measured by compliance with specific regulations or ecological standards. While scientifically sound, such methods are not fully aligned with the socio-economic conditions of independent smallholders. By combining three sources of governance into a complementary system, this study expands upon these earlier frameworks. *Lubuk larangan* strengthens social legitimacy and sustainability through local values, formal regulations provide a legal foundation, and RSPO guidelines offer scientifically grounded technical direction. All of these components can interact dynamically through adaptive collaborative management.

As a result, management does not focus solely on compliance but also on community learning and empowerment. This study therefore bridges the gap between social practices and technical science by proposing a riparian management model that is actionable, sustainable, and rooted in the local context of independent smallholders. The findings of this study indicate that there are both theoretical and practical strategic implications for developing an integrative framework for riparian zone governance. This framework combines three core pillars of collaborative environmental governance: formal regulation, ecological technical guidelines, and local knowledge. The study also emphasizes the importance of applying an adaptive co-management approach as a foundation for collaborative environmental governance. In this context, adaptive co-management is understood as a social learning process that enables changes in social norms, technical practices, and policy.

The main implication of this study is that the integrative framework serves as a platform for three fundamental principles of adaptive co-management: collaboration, co-regulation, and social learning. First, the principle of collaboration asserts that riparian zone management cannot be carried out by a single group alone. Planning, implementation, and monitoring must involve government institutions, local communities, and certification bodies such as RSPO. When stakeholders work together, they create a space where actors can engage as equals, allowing local knowledge, science, and law to complement one another (Berkes, 2009; Lemos & Agrawal, 2006). This implies the need for institutional reform, which can be supported through the establishment of local multi-stakeholder forums that are participatory and sustained to address riparian conservation.

Second, co-regulation highlights the importance of legal recognition for social practices and customary values that have demonstrably produced positive socio-ecological outcomes. *Lubuk larangan*, a local tradition in Jambi, functions not only as a customary rule for restricting fishing but also as an informal mechanism supporting formal conservation goals (Lubis et al., 2019; Suryahartati et al., 2021). If local governments provide legal recognition for such customary systems—through village regulations or integration into spatial planning (RTRW) and Strategic Environmental Assessments (KLHS)—the legitimacy of environmental policies will increase. In this process, the position of local communities as primary conservation actors is strengthened, forming a symbiotic relationship between state law and local value systems.

Third, the sustainability of this framework depends on the concept of social learning. Social and ecological conditions in riparian management continue to evolve due to economic pressures, climate change, and land-use conversion. Consequently, adaptive learning mechanisms are required, enabling continuous evaluation and adjustment of conservation policies and practices (Holling, 1978; Berkes, 2012). Social learning also facilitates knowledge exchange between formal actors (government, academics) and local actors (smallholders, customary leaders). Thus, environmental management is not solely driven by administrative compliance but develops as a process of collective learning.

Adaptive Riparian Zone Governance is grounded in three principles of adaptive co-management, focusing on legitimacy, effectiveness, and social acceptance (Ostrom, 2010; Plummer et al., 2012). First, legitimacy arises when communities believe they have a direct role and responsibility in managing the river. Recognition of customary values such as *Lubuk larangan* enhances the social legitimacy of conservation policies. Compliance then emerges from collective awareness of shared benefits rather than enforcement pressure. Second, effectiveness is achieved through the application of technical guidelines tailored to local ecological conditions, such as the use of native vegetation for revegetation and the prohibition of chemical use in riparian zones (RSPO, 2017; 2021). Because adaptive approaches are supported by social capital and local resources, conservation efforts become more effective. Third, social acceptance increases when conservation policies do not conflict with cultural values and the economic needs of the community. The system balances environmental protection with community well-being.

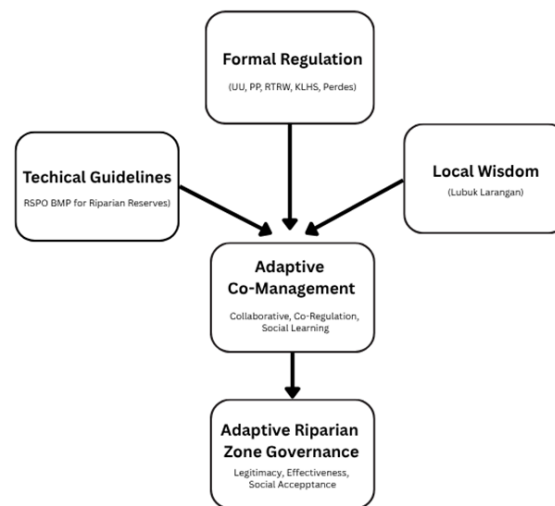


Fig. 1. Integrative framework for riparian zone management by independent smallholders

This framework implies that local governments can adopt community-based riparian management models grounded in adaptive cooperation at the local level. The model can be incorporated into watershed rehabilitation programs or village development policies through village funds and collaborations with private institutions. The results of this study, as visualized in Figure 1, can serve as the basis for reformulating plantation policies nationwide to make them more responsive to local socio-ecological factors. By integrating RSPO technical guidelines, national regulations, and customary systems, there is potential to enhance conservation efficiency and strengthen the legitimacy of Indonesia's environmental policies in the international arena (Colchester et al., 2011; Jelsma et al., 2019).

This study shows that formal legal instruments and policy frameworks are not the only factors determining the effectiveness of natural resource governance. It also highlights the extent to which social mechanisms and collective learning are incorporated into the system. Therefore, its theoretical implications lie in strengthening the paradigm of polycentric governance (Ostrom, 2010), in which environmental decisions and responsibilities are distributed across multiple levels from local communities to national institutions that coordinate adaptively. Overall, this integrative framework opens new pathways toward more just, inclusive, and sustainable riparian zone governance. The method of adaptive co-management, which emphasizes collaboration, co-regulation, and social learning, is expected to support the development of a plantation zone management system that ensures social legitimacy, technical effectiveness, and community acceptance. This model can be used as both a theoretical and practical reference for environmental policymaking in smallholder plantation landscapes in Indonesia.

4. Conclusions

This study provides a broader understanding of how various institutional instruments interact and influence riparian management practices at the site level by integrating regulatory, technical, and socio-cultural dimensions. The analysis shows that riparian management is the result of the interplay among legal frameworks, technical capacity, and long-established local values within the community. The existing regulatory framework has provided normative guidance on the ecological functions of riparian zones; however, its effectiveness is shaped by the socio-economic variability of independent smallholders and the limitations of technical support. Meanwhile, technical guidelines offer a robust scientific foundation for riparian protection and restoration, but their implementation does not always align with field capacities. Owing to their strong local legitimacy, socio-cultural practices within communities demonstrate significant ecological and social potential.

Nevertheless, these practices are not yet fully formalized within official frameworks, making them vulnerable to policy shifts and land-use changes. In this context, *Lubuk larangan* can serve as a socio-ecological instrument to strengthen riparian management through community-based regulatory mechanisms, given its normative role in restricting resource use and maintaining aquatic ecosystem quality.

The findings suggest that adaptive co-management should be employed as a management framework capable of connecting and balancing these three dimensions. This approach enhances community roles in decision-making and enables continuous adaptation. Adaptive co-management has the potential to reconcile the gaps between ecological demands, policy interests, and operational realities faced by independent smallholders by adopting more participatory and flexible mechanisms. Several recommendations arise to improve governance, including stronger coordination among actors, the provision of incentives for smallholders who have implemented best management practices, and the strengthening of community-based monitoring. It is crucial to develop more context-specific technical guidelines, enhance community capacity to monitor riparian conditions, and provide more organized institutional support from local governments and partner organizations. Recognizing local practices and integrating them into joint management mechanisms can also enhance legitimacy and promote long-term sustainability. This study opens opportunities for further research, particularly on how adaptive co-management can be applied in diverse and dynamic socio-ecological conditions. At the site level, the conceptual framework developed here can be strengthened through studies on implementation effectiveness, actor collaboration dynamics, and the outcomes of integrated management practices. Overall, this study provides a strong academic foundation for developing a riparian governance model in smallholder plantation landscapes that is more inclusive, adaptive, and sustainable. It also offers relevance for long-term decision-making processes.

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Author Contribution

The author conceptualized the study, developed the methodology, collected and analyzed the data, interpreted the findings, drafted and revised the manuscript, and approved the final version.

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Conflicts of Interest

The author declares no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author used Turnitin and Grammarly to assist in refining the grammatical structure, enhancing academic vocabulary, and improving the clarity of the narrative flow. After using this tool, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Biography of Author

Maria Roswita Kartika Sari Bawono, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta, 10430, Indonesia.

- Email: mariaroswita.ksb@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A