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Navigating Challenges and Opportunities in Sustainable Natural Resources Management in Long Pahangai District

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ABSTRACT
Long Pahangai District, located in Mahakam Ulu Regency, East Kalimantan, has significant natural resource potential in forestry, agriculture, plantations, and ecotourism. However, this potential remains underutilized due to isolation, weak infrastructure, and ecological degradation. The importance of this research lies in discussing the limited academic attention to sustainable natural resource management (SNRM) in remote border areas that face governance and development asymmetry. Unlike previous research centered on accessible areas, this study fills the gap by examining the potential and barriers of SNRM in Long Pahangai, where indigenous ecological knowledge interacts with fragile institutional systems. This study uses a qualitative systematic literature review (SLR) using thematic content analysis of academic publications, government reports, and local initiatives. The data are categorized into thematic clusters to identify contextual patterns of sustainability. These findings reveal substantial potential, including strong traditional forest management, adaptive agroforestry practices, and the growth of community-based ecotourism. Instead, the main obstacles consist of poor transportation infrastructure, limited renewable energy capacity, ongoing deforestation, and low technology adoption. Conceptually, this research contributes to the discourse of polycentric environmental governance by positioning border areas as critical but marginalized spaces for sustainability innovation. It highlights how integrating indigenous institutions with local governments and civil society can foster ecological resilience and balance. The study recommends policy directions focused on community empowerment, decentralized renewable energy, and participatory ecotourism development. Future research should include participatory fieldwork to enrich the empirical foundation and validate the dynamics of adaptive governance in Indonesia's border regions.

Keywords: Sustainable Resource Management, Customary Knowledge, Environmental Degradation, Community-Based Management, Border Land Development Policy.

I. Introduction

Indonesia, as an archipelagic country rich in natural resources, faces complex challenges in achieving sustainable management. Efforts to balance the use of natural resources for economic development and environmental preservation remain a major concern in both policy and academic discussions. East Kalimantan—particularly Mahakam Ulu Regency—vividly illustrates this complexity. Based on data from the

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Central Statistics Agency of Mahakam Ulu Regency (2023), this district covers an area of approximately ±18,427 km^2, dominated by tropical rainforest ecosystems and the Mahakam River, which functions as a vital transportation route and the center of socio-economic activities (Central Statistics Agency of Mahakam Ulu Regency, 2025). Within this district, Long Pahangai District stands out for its significant natural resource potential. Geographically located on the Indonesia–Malaysia border, Long Pahangai has distinct ecological features, including mountains, dense forests, and rivers that sustain local livelihoods. The area's fertile land supports agriculture—particularly cocoa and rice cultivation—while its eco-friendly potential is characterized by natural attractions such as the Keneheq Waterfall in Long Tuyoq Village, which attracts both domestic and international visitors (Prokopim Mahakam Ulu, 2023; Alquran Kaltara, 2022).

However, despite this abundance, the region faces persistent challenges in realizing sustainable management. Limited infrastructure, coupled with geographical isolation, restricts accessibility and the movement of goods and services. These logistical barriers not only hinder agricultural distribution but also limit tourism growth. In addition, deforestation and forest degradation, driven by unsustainable extraction practices, pose a serious threat to environmental integrity and community livelihoods (Priambodo, 2023; Imran, 2024). From a theoretical perspective, border regions occupy a unique position in governance and sustainability discussions. As Newman (2006) notes, borders are not merely administrative demarcations but dynamic spaces of socio-economic and ecological interaction. Effective management in such regions, therefore, requires a contextual and adaptive approach, given the diverse intersections of customary law, cross-border exchanges, and ecological interdependence.

Meanwhile, the environmental justice framework highlights that communities in marginalized areas often face inequities in the distribution of environmental benefits and burdens (Risse, 2011; Schlosberg, 2007). This aligns with the findings of Cons and Sanyal (2013), who observed that border areas frequently suffer from institutional weaknesses, overlapping jurisdictions, and infrastructure deficits. Similarly, Spies and Alff (2023) emphasized that on the borders of China and neighboring countries, local communities often lose land and economic autonomy due to the dominance of external actors and centralized policies. While these studies offer valuable insights, there remain glaring gaps in the literature regarding border regions that are highly isolated and disconnected from state infrastructure or governance mechanisms. Existing research tends to focus on border areas with administrative integration or established cross-border cooperation frameworks. As a result, areas such as Long Pahangai—representing structurally marginalized and geographically extreme regions—remain understudied in the discourse on sustainable border governance.

To address this research gap, this study seeks to answer two main research questions:

a. What are the main obstacles to achieving sustainable natural resource management in Long Pahangai District?
b. What potential strategies can be developed to optimize local resource management in accordance with the principles of sustainability and community needs?

By formulating these questions explicitly, this research aims to provide a clearer analytical direction and contribute to a deeper theoretical understanding of adaptive management in peripheral border regions. Beyond its academic contributions, the findings are expected to inform policy formulation aligned with local socio-ecological realities, promoting a more inclusive and sustainable governance model for Indonesia's border regions.

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II. Literature Review and Hypothesis Development

Natural resources are essential for human life, economic growth, and ecological balance. They encompass various forms of natural wealth—such as water, air, land, minerals, fisheries, and forests—that sustain life systems and form the material, economic, and cultural foundations of societies. However, their status as a common-pool resource (CPR) makes them vulnerable to overexploitation and degradation when access and benefits are not effectively regulated (Berkes, 2021).

2.1. A Classic Perspective on Resource Depletion

The vulnerability of shared resources was originally theorized by Hardin's concept of the Tragedy of the Commons, which posits that individuals acting rationally in their personal interest can collectively overexploit shared resources (Hardin, 1968). This deterministic model has been widely criticized for underestimating human cooperation, institutional diversity, and socio-ecological variability. To overcome these limitations, scholars emphasize that societies are often capable of self-management through shared norms, trust, and collective sanction mechanisms (Dietz et al., 2003). Further empirical research confirms that community-based resource management can be effective in certain socio-ecological conditions, such as small-scale fisheries, irrigation systems, and community forests (Baggio, Barnett, Perez-Ibarra et al., 2016; Partelow, 2018a; Vogt et al., 2015a). Nevertheless, critics argue that such models can be overly optimistic, assuming homogeneity of interests and the stability of local institutions.

2.2. Evolving Models: From Community Management to Polycentric Governance

In response to these critiques, recent governance literature promotes a polycentric approach characterized by multiple overlapping decision-making centers operating across scales. This framework enhances adaptability, learning, and coordination between local, regional, and national institutions. Polycentric governance has proven relevant in complex contexts such as border areas, where indigenous peoples, local governments, private companies, and NGOs interact in managing natural resources (Carlisle & Gruby, 2017; Morrison, Adger, Brown, Lemos, Huitema, Pahl-Wostl et al., 2019).

2.3. Sustainable Development and the Triple Bottom Line

The principles of sustainable development, as articulated by the World Commission on Environment and Development (WCED), underscore the balance between meeting present needs and conserving resources for future generations. In economic terms, sustainable management requires internalizing environmental costs into policy decisions to control resource exploitation (Pearce et al., 1990). One of the influential analytical models is the Triple Bottom Line (TBL) framework, which integrates economic, social, and environmental dimensions. Economically, sustainability involves efficient utilization and diversification of income to reduce dependence on resource extraction. Socially, participatory governance and equitable distribution of benefits strengthen legitimacy and compliance. Environmentally, conservation and rehabilitation support long-term resilience (Elkington, 1998; N. J. Bennett, 2017; Esparza et al., 2024; Kenter et al., 2019; Partelow, 2018a). Nonetheless, scholars note that TBL approaches may be normative and not sufficiently responsive to the political and institutional conflicts inherent in real-world settings.

2.4. Integrating Political Ecology and Power Relations

To address the limitations of technocratic or apolitical sustainability models, the political ecology perspective emphasizes how power relations, market dynamics, and policy frameworks shape access, control, and sustainability outcomes. In this sense, sustainability is not only an ecological or economic challenge but

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also a matter of justice, recognition, and political negotiation among actors (Blaikie & Brookfield, 2015; Robbins, 2020). Integrating the Tragedy of the Commons, Commons Theory, Polycentric Governance, and the Triple Bottom Line through the lens of political ecology provides a more comprehensive understanding of sustainable natural resource management. Effective management thus depends not only on local institutional capacity but also on multi-scale coordination, adaptive regulation, and sensitivity to socio-ecological and political contexts. In this study, such conceptual synthesis forms an analytical foundation for examining how policy design, community capacity, and stakeholder interactions shape the sustainability of natural resource management in vulnerable and dynamic border areas such as Long Pahangai Regency.

III. Research Method

This study uses a qualitative approach using the systematic literature review (SLR) method to explore the potential and obstacles of sustainable natural resource management (SNRM) in Long Pahangai Regency. In this context, sustainable natural resource management refers to the integrated process of utilization and conservation of natural resources: forests, soils, water, and biodiversity, thereby maintaining their ecological functions while meeting current and future human needs. This definition serves as an analytical boundary for the study and is in line with the principles of sustainability promoted by the World Commission for Environment and Development (WCED, 1987). The use of a systematic literature review was chosen due to the remote geographical location of Long Pahangai Regency, which presents logistical constraints for primary data collection, such as field observations or in-depth interviews. This method allows researchers to synthesize knowledge from diverse and credible sources to generate new theoretical and empirical insights on sustainable resource management in isolated border regions. The originality of this approach lies in its focus on the context of peripheral governance, integrating environmental policy analysis, community-based management, and border development, areas that were rarely examined together in previous studies of East Kalimantan.

Data were obtained from peer-reviewed journals, academic books on resource management and sustainable development, previous research reports, and official policy documents such as Government Regulations, Mahakam Ulu Regent Regulations, and Mahakam Ulu Regency Medium-Term Development Plan (RPJMD). Statistical data is collected from agencies such as BPS Mahakam Ulu, while additional contextual information comes from leading online media such as Prokopim Mahakam Ulu. These diverse sources allow for a multi-perspective understanding of institutional, ecological, and socio-economic dynamics. Data collection follows a systematic procedure through targeted searches on platforms such as Google Scholar, Journal Articles, and News Articles. The inclusion criteria are: First, Direct relevance to sustainable natural resource management or remote area development, Second, Publication in the last ten years (2015–2025); and Third, Credibility of sources and publishers. Documents that meet these criteria are downloaded, organized, and archived using Mendeley, a reference management software that helps in cataloging and tracking citations. For readers unfamiliar with the tool, Mendeley facilitates systematic documentation, annotation, and retrieval of academic sources, ensuring transparency and replicability in literature-based research.

Data were analyzed using descriptive qualitative analysis with a thematic analysis approach, the processes involved; First, Initial introduction, comprehensive reading to understand contextual meaning; Second, Open coding, identifies relevant citations that highlight potentials, challenges, and strategies; Third, theme development, grouping code into broader categories that reflect repetitive patterns; Fourth, refinement of themes, merging, separating, or redefining themes for conceptual coherence; and Fifth, Interpretation and synthesis, integrating themes across the document to identify cross-sectoral insights. Thematic analysis was chosen because it allows the extraction of conceptual relationships between policy narratives, community practices, and environmental dynamics. The resulting themes form the basis for building theoretical synthesis and drawing policy implications tailored to remote areas. To improve methodological accuracy, source triangulation is applied by comparing data from different types of

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documents, academic literature, government reports, and statistical data, to verify consistency and minimize bias. However, some limitations remain. This approach relies heavily on document availability and cannot capture real-time or community-level dynamics. Limited empirical validation through direct observation can limit contextual depth. However, these constraints are mitigated by cross-verifying sources, emphasizing methodological transparency, and placing findings within the broader framework of polycentric environmental governance. In summary, this literature-based approach offers a new contribution to the discourse on sustainable resource governance by showing how thematic synthesis can uncover adaptive management strategies in under-researched border regions. It expands the existing framework by linking ecological, institutional, and socio-cultural dimensions, thereby enriching the theoretical landscape of sustainable natural resource management in remote areas of Indonesia.

IV. Results and Discussion

4.1. Natural Resources Potential: Forestry, Agriculture, Plantations, Ecotourism

This chapter presents research results on sustainable natural resource management in Long Pahangai District, Mahakam Ulu Regency, as well as an in-depth analysis of supporting factors, barriers, and community-based management strategies. The findings of this study are discussed by referring to various theories and previous research, while highlighting the original contribution of the research to the literature on community-based resource management in border areas. The main contribution of this research lies in a new understanding of the dynamics of natural resource management in remote border areas, a geographical context that has been under-appreciated in academic studies. This research reveals how local practices based on customary wisdom are able to create adaptive management mechanisms, even though they are economically and politically marginal. In addition, this study expands the application of polycentric governance frameworks in the context of rural Indonesia by linking the role of communities, local governments, and NGOs in resource management. In this chapter, each subsection begins with a transition that guides the reader to understand the relationship between empirical findings and theoretical foundations. The results of the study are categorized into four main aspects of resource potential, forestry, agriculture, plantations, and ecotourism, as well as four main obstacle groups, namely infrastructure, energy, deforestation, and technology. Furthermore, community empowerment strategies, strengthening renewable energy, and developing locally-based ecotourism were discussed.

a. Forestry: Indigenous Wisdom and Ecological Resilience

Research shows that Long Pahangai District in the upper Mahakam River basin possesses significant forestry potential, characterized by extensive protected forests, production forests, and customary forests. Local communities actively utilize a variety of non-timber forest products (NTFPs)—including resin, rattan, honey, agarwood, and forest fruits—as major sources of income and as the foundation of traditional economic resilience. These resources are managed through robust local mechanisms based on customary norms, mutual agreements, and social sanctions that ensure sustainable forest use, even though the region is located on the border and has limited infrastructure access. These findings align with Baggio et al. (2016), who demonstrated that community-based management of NTFPs can significantly reduce the rate of local deforestation, even though it cannot fully mitigate external economic pressures. However, Epstein (as cited in Vogt et al., 2015a) noted that self-governing models remain vulnerable to intrusion by timber companies and commercial interests that undermine customary authority. Similarly, Ramadhan et al. (2021) found a comparable dynamic in Tonggong Hamlet, West Kalimantan, where oil palm expansion led to secondary deforestation. In contrast, the people of Long Pahangai District have shown a greater ability to maintain NTFP diversification as an adaptation strategy.

This suggests that the strength of local institutions varies across regions depending on the legitimacy of customary norms and the collective capacity of communities. These observations reinforce Carlisle and Gruby's (2017) argument regarding the importance of polycentric governance—multi-centered management involving local communities, local governments, and non-state actors—as a means of enhancing resilience against external economic and policy pressures. Research conducted in Long Pahangai District thus offers new

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insights: the success of community-based forest management in border areas depends not only on ecological wealth but also on the collective capacity of communities to integrate traditional knowledge with adaptive institutional innovation. This indicates that the diversification of NTFPs, when integrated with customary norms, can serve as an early indicator of sustainable natural resource management success—even in contexts with weak national policies. Consequently, a multi-center management strategy emphasizing cross-scale coordination, conservation incentives, and local institutional strengthening represents an effective approach to building ecological and social resilience. This model challenges the dominant assumption that peripheral areas can only progress through large-scale external interventions, while offering opportunities for replication in other regions with similar socio-cultural and ecological conditions.

b. Agriculture: Traditional Integration and Agroforestry Adaptation

The findings reveal that agriculture in Long Pahangai District remains largely traditional, dominated by shifting cultivation practices. Contrary to the common assumption that shifting cultivation is the main cause of deforestation, local communities have developed culturally rooted agroforestry patterns. They integrate rice, sugarcane, and coffee with fruit and hardwood trees that protect the land and support the micro-ecosystem. This approach maintains soil fertility, enhances household food productivity, and ensures sustainable income through crop diversification. This adaptation model is consistent with Sutrisno et al. (2024), who found that improved tree-based and multifunctional agroforestry systems enhance food security, household income, and climate change mitigation through carbon sequestration.

The findings also support the revised perspective of Commons Theory, which emphasizes that the success of shared resource management depends on the combination of social norms, regulatory transparency, sanction mechanisms, and local institutional legitimacy (Baggio, Barnett, Ibarra et al., 2016; Partelow, 2018a). In Long Pahangai District, land rotation and secondary vegetation management are collectively regulated through customary agreements, reflecting a strong capacity for self-governance. However, these findings also confirm that community governance is not always stable in the long term—particularly when external pressures such as population growth, plantation expansion, or changes in land policy arise. Morrison et al. (2019) emphasize that in complex governance contexts, the success of local innovation cannot rely solely on community capacity but also requires multi-stakeholder coordination among communities, local governments, and supporting organizations.

Thus, this study provides new insights that shifting cultivation is not necessarily synonymous with deforestation or degradation when integrated with collectively agreed agroforestry principles. The model in Long Pahangai District demonstrates that sustainable traditional agriculture is achievable when customary conservation norms, land rotation mechanisms, and institutional assistance are synergized. These findings challenge the outdated narrative that labels shifting cultivation as an absolute ecological threat and instead open opportunities for contextual policy reforms. Furthermore, this locally based agroforestry model can be replicated in other border regions of Indonesia and developing countries with similar socio-ecological contexts. It supports the *Triple Bottom Line* framework, as proposed by Bennett (2017), which emphasizes simultaneous sustainability in economic, social, and environmental dimensions through community-based adaptation strategies.

c. Plantations: Economic Diversification and Conservation

The plantation sector in Long Pahangai District has gradually developed through smallholder models that integrate permanent plantations with secondary forests. The main commodities cultivated include rubber, coffee, cocoa, and pepper, using semi-intensive systems that maintain ecological structure. A notable finding is the development of locally hybrid coffee cultivated under natural shade trees, reflecting agroforestry-based coffee systems that promote biodiversity conservation. From a *Triple Bottom Line* perspective, this plantation practice yields economic benefits through income diversification, social benefits through strengthened cooperation, and environmental benefits through the maintenance of secondary forest mosaics.

These findings are consistent with Moguel and Toledo (1999), who found that natural canopy coffee plantation systems support higher biodiversity than monocultural plantations. Structural barriers, such as limited market access, inadequate distribution facilities, and basic post-harvest technologies, were also identified, aligning with Rodela's (2019) finding that weak infrastructure contributes to value-chain failures in

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rural Indonesia. Moreover, the dynamics of power relations among local communities, district governments, and the private sector reflect Robbins' (2012) argument in political ecology that plantation policies often favor large-scale investment, reducing opportunities for smallholders. Nevertheless, contrary to the deterministic assumptions of the *Tragedy of the Commons*, the success of the agroforestry model in Long Pahangai District demonstrates the capacity of local communities as key actors in maintaining sustainable practices.

Overall, the observed phenomenon provides new insights that small-scale agroforestry-based plantations can grow endogenously and function as conservation instruments in border areas. This challenges the development narrative that regards large-scale investment as the only route to improve productivity and welfare. Instead, strengthening community capacity, customary-based social capital, and multi-stakeholder coordination within a polycentric governance framework can build plantation systems resilient to market fluctuations and policy uncertainty. Furthermore, plantation development in remote areas should avoid industrial land conversion schemes and instead adopt hybrid strategies that integrate agroforestry approaches, property rights protection, and small-scale targeted investments—such as post-harvest technology improvements and market access enhancement—to achieve a balance between economic well-being and ecological sustainability.

d. Ecotourism: Cultural Integration and Nature Conservation

The study on ecotourism in Long Pahangai District reveals substantial potential grounded in tropical rainforest landscapes, Dayak cultural heritage, and preserved biodiversity. One of the most notable attractions is Keneheq Waterfall, renowned for its scenic beauty and sacred value among the local indigenous people. Other potential attractions include trekking routes to primary forests, observation of endemic wildlife, and visits to traditional *lamin* (longhouses) still used for cultural rituals. The community has initiated independent ecotourism management through family-run homestays, local guide services, and tour packages that integrate natural and cultural experiences. Although not yet fully incorporated into the district's tourism policy, these activities have become additional income sources for families, cooperatives, and youth groups.

These findings are consistent with Stone and Nyaupane (2019), who demonstrated that community-based ecotourism improves socio-economic well-being when developed through active local participation. However, the development of tourism at Keneheq Waterfall and other destinations still faces challenges such as limited river transport access, inadequate infrastructure, and uncoordinated promotion efforts. This aligns with Scheyvens and Hughes (2019), who found that tourism in remote regions often progresses slowly due to weak institutional capacity, insufficient marketing, and limited support. Nevertheless, these constraints have not prevented the people of Long Pahangai from initiating self-managed tourism ventures. The early success of Keneheq Waterfall as a tourism icon stems primarily from community initiatives rather than external assistance programs.

Hence, this study provides new insights that ecotourism development in remote border regions can begin by optimizing authentic local attractions—such as Keneheq Waterfall—integrated with cultural narratives and customary conservation practices. The findings confirm that a gradual, community-driven approach can establish a more resilient ecotourism industry than externally imposed projects. Furthermore, policy interventions should focus on strengthening community institutions, enhancing cross-platform promotion, and investing in context-appropriate small-scale infrastructure. Keneheq Waterfall and its surrounding ecosystem thus serve not only as alternative economic resources but also as instruments for environmental conservation and the reinforcement of cultural identity among marginalized border communities.

4.2. Barriers: Infrastructure, Energy, Deforestation, Technology

a. Infrastructure

Infrastructure in Long Pahangai District remains very limited. Overland access from Long Bagun is inadequate due to muddy or potholed roads, decaying wooden bridges, and landslides at critical points (e.g., at Kilometer 19 before the Palu River). As a result, communities rely heavily on the Mahakam River. During dry or rainy seasons, unstable road conditions directly affect logistics and staple prices. Although emergency measures—such as road filling and temporary wooden bridge construction—have been carried out by the Public Works and Public Housing Service and the Indonesian National Armed Forces, permanent repairs are

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still pending and await firm budget allocations from the province or central government (Teodorus, 2023; Wanto, 2025a, 2025b). This situation can be explained through a political ecology lens, which examines how politics and policy shape environments and livelihoods. Certain regions may be structurally marginalized, receiving insufficient investment in roads, schools, and health services, thereby reinforcing long-term (structural) poverty and weakening communities' capacity to manage natural resources fairly and independently. Consistent with this, remote tourism often develops slowly due to weak institutional capacity—e.g., limited managerial skills, lack of coherent marketing, and insufficient ongoing mentoring (Scheyvens & Hughes, 2019).

Even so, Long Pahangai shows that adaptive approaches combining local initiatives and multi-level governance support can work. For example, the relocation of Bailey bridges and emergency road repairs by the Regional House of Representatives (DPRD) and the Indonesian National Armed Forces (TNI) indicate participatory management of critical infrastructure. Thus, solutions in remote areas are not only about physical construction but also about governance arrangements that involve communities, local governments, and the center to enable faster, more targeted responses. This model is relevant for other Indonesian border regions where social capital and multi-actor cooperation can effectively fill state infrastructure gaps (Daung, 2025).

b. Energy

Since 2018, several villages in Long Pahangai—such as Long Pakaq Baru and Delang Kerohong—have enjoyed 24-hour electricity following the installation of communal solar plants (≈60–64 kWp), replacing prior reliance on diesel generators. Previously, high operating costs (≈Rp 600,000/month/household) limited many families to ≈4 hours/day of electricity; solar power has substantially reduced costs while extending service hours (Ghofar, 2019). However, renewable energy use still faces challenges. A shortage of trained local technicians hinders routine maintenance and troubleshooting. Supporting infrastructure (roads, equipment, communications) is limited, slowing spare-part distribution and technical assistance. Other alternatives (e.g., micro-hydro, biogas) are constrained by limited knowledge and human resources. These barriers mirror political-ecology analyses and evidence that border-area energy access is hampered by infrastructure constraints and development inequalities (Morrison, Adger, Brown, Lemos, Huitema, Phelps, et al., 2019). Related literature also notes that the potential of micro-hydro and biogas is underutilized due to limited technical capacity and institutional support (Fitriaini, 2022). Accordingly, communal renewable systems (PLTS, micro-hydro) must be paired with local capacity building and institutional strengthening (e.g., BUMKam for electricity management). Polycentric governance—linking communities, local government, NGOs, and private actors—can enable replication elsewhere and position clean, self-sufficient energy as a driver of empowerment and mitigation of socio-ecological inequalities.

c. Deforestation

In Long Pahangai, deforestation is driven not only by shifting cultivation but also by forest concessions (HPH, HTI). Tenure conflicts arise when Indigenous peoples resist clearance on customary lands while plantation pressures persist. In some hamlets, primary and secondary forest cover reportedly declined by 10–15% over the last decade, increasing erosion, reducing spring flows, and amplifying flash-flood risk during heavy rains. Political ecology emphasizes that national frameworks often prioritize extractive industries over local tenure rights. Empirical work in West Kalimantan similarly documents how conversion to large-scale plantations exacerbates secondary deforestation (Ramadhan et al., 2021). Mitigation is most effective when legal recognition of customary forests is combined with polycentric governance mechanisms and incentives for sustainable practices (e.g., payments for environmental services). The Long Pahangai case suggests that cross-scale "safety nets" (customary–district–central–NGO) can temper industrial pressures while maintaining ecological functions—offering a replicable approach for other border regions with similar tenure conflicts.

d. Technology

Farmers face serious obstacles to adopting modern technologies. Most still rely on hoes and sickles, with minimal access to machinery, efficient irrigation, or modern inputs. Internet access is very limited, curtailing the feasibility of IoT tools, pest apps, or drone monitoring. Education and training gaps persist; youth's reluctance to learn new tools further delays uptake (Ghofar, 2017; Rain, 2023). At the national level, regulations and bureaucracy can impede agricultural technology diffusion, keeping farmers from modern

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tools even when they exist domestically. Experience from Tana Tidung (North Kalimantan) shows that tool availability alone is insufficient when farmer institutions are weak, and adoption remains low. While IoT e-farming models can raise efficiency, poor connectivity and limited technical capacity render them impractical without investments in local infrastructure and training (Cyber Extensions, 2019; Mansur, 2018; UMA Agriculture, 2023). Thus, technology programs should be contextual and participatory. Rather than merely introducing devices or apps, establish farmer groups/equipment units, secure budgets for training and maintenance, and embed local governance for operation and accountability. A polycentric approach can bolster technological resilience, enabling scalable, sustainable adoption aligned with community needs and culture.

4.3. Strategy: Community Empowerment, Renewable Energy, Local-Based Ecotourism

a. Community Empowerment

Empowerment efforts include forming farmer groups and village cooperatives to manage resource access, alongside trainings for agroforestry, ecotourism homestays, and communal PV maintenance—engaging youth and women. Local farmer field schools provide hands-on, participatory learning that supports collective decision-making, enterprise planning, and basic technical skills for maintenance and processing. This aligns with community-based agro-silvopastoral frameworks that emphasize training, technical support, mentoring, and multistakeholder coordination (Sunariyo & Firdausi, 2024). Indonesia's Social Forestry Program likewise stresses legal access and strengthened capacity of Indigenous Peoples and Local Communities (IPLCs) for local economic development and conservation (World Bank Group, 2021). Farmer field schools have been shown to foster practical knowledge, promote agroecological adoption, and catalyze socio-economic empowerment. The Long Pahangai experience indicates that empowerment must build technical, institutional, and social resilience. A scalable blueprint combines social-forestry legalization of access with intensive training, participatory institutional support (co-ops, groups, NGOs), and market linkages—an embodiment of polycentric governance for ecological and economic sustainability.

b. Renewable Energy

Since 2018, communal PV systems (≈60–64 kWp) in villages like Long Pakaq Baru and Delang Kerohong have replaced costly diesel generators (≈Rp 600,000/month/household; only a few hours/day), while pilot micro-hydro and biogas initiatives have emerged but remain underdeveloped due to technical and capacity constraints. Sustainability improves when systems have community ownership, adequate operator training, and local management institutions (e.g., electricity co-ops). Persistent challenges include institutional readiness, weak enabling regulations, and limited access to funding and wider grids. Centralized solar systems are effective only when communities participate and contribute to technical support and operating budgets (Barsei et al., 2024). The case suggests renewable strategies work best under polycentric governance—collaborative energy management among communities, local government, NGOs, and private actors. Revitalizing small PV systems via cooperatives/BUMKam, paired with technical training and options for on-grid value, can improve efficiency and quality of life (e.g., evening schooling, resource processing) and strengthen socio-ecological resilience—generalizable to other remote regions.

c. Local-Based Ecotourism

Long Pahangai is developing nature- and culture-based ecotourism, with Keneheq Waterfall as a natural icon and the Hudoq Dance as a cultural icon. Activities include rainforest trekking, endemic wildlife observation, and cultural immersion via *lamin* homestays. Local CBOs provide tour packages, guides, and basic accommodation managed by the community. Although not yet formally supported by district policy, these initiatives provide alternative income and employment—especially for youth and women. Cultural programming (e.g., Hudoq Pekayang performances, rice-season rituals, "Long Ear" documentation, and cross-border promotion) is advancing through local-government collaboration, extending to villages such as Batu Majang with notable tourism potential (Wanto, 2024). This model aligns with community-based ecotourism (CBET), where local participation and ecosystem-service stewardship are foundational (Giriwati et al., 2019; Manaf et al., 2018). Classic constraints persist—limited infrastructure, waste-management issues, and weak digital promotion—underscoring the need for institutional strengthening. Multi-stakeholder collaboration

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among communities, governments, NGOs, and tourism enterprises is key to sustaining and improving quality. Overall, optimizing nature-culture ecotourism is most effective when participatory, authentic, and context-sensitive. Gradual strategies that leverage social capital and cultural values can build resilient models of economic sustainability and conservation—replicable in other border areas with similar ecological and cultural assets.

V. Conclusion

The findings of this study reveal that sustainable natural resource management in Long Pahangai District operates in a dual dynamic of opportunities and constraints. On the one hand, the region has rich ecological and cultural assets, forests with high biodiversity, adaptive agroforestry systems, smallholder plantations, and emerging ecotourism potentials rooted in indigenous traditions. It provides a solid foundation for community-based management. On the other hand, structural limitations such as inadequate infrastructure, limited access to renewable energy, persistent deforestation, and limited technological capacity continue to hinder sustainable progress. The analysis shows that the interaction between local adaptive practices and broader institutional frameworks determines the level of sustainability achieved in these peripheral border regions. Thus, the main research objective, to identify and analyze the potentials and obstacles of sustainable natural resource management, has been successfully achieved through a comprehensive thematic synthesis.

Conceptually, this study contributes to advancing theoretical dialogue on polycentric governance and political ecology by positioning border areas as critical but understudied spaces of environmental governance. Methodologically, it shows how a systematic literature review combined with thematic analysis can generate contextual insights for remote regions with limited empirical data. Theoretically, the integration of commons theory, polycentric systems, and triple bottom line frameworks enriches the understanding of sustainability as an ecological and political process. Thus, this research expands the conceptual boundaries of sustainable governance by linking environmental justice, institutional diversity, and indigenous knowledge systems in the specific realities of Indonesia's borders.

Despite its contributions, the study has inherent limitations in its reliance on secondary data. The absence of field-based observation and stakeholder interviews limits its capacity to capture lived experiences, power dynamics, and evolving local practices in real time. Therefore, future research should use participatory and ethnographic methods to validate and deepen these findings, especially regarding the interaction between customary law, policy implementation, and ecological adaptation. Addressing these gaps will enable a more comprehensive understanding of how sustainability can be locally based yet institutionally supported, offering actionable insights for sustainable border governance and equitable management of natural resources in Indonesia and beyond.

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