JURNAL AR RO'IS MANDALIKA (ARMADA)
Journal website: https://ojs.cahayamandalika.com/index.php/armada

ISSN: 2774-8499 Vol. 6 No. 2 (2026)

Research Article

Community-Based Strategies for Sustainable Peatland Ecosystem Protection

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Abstract

Tropical peatland ecosystems play a crucial role in global climate regulation by storing large amounts of carbon, yet they continue to experience severe degradation due to drainage, land conversion, and recurring fires. Conventional peatland restoration approaches that rely solely on technical interventions often fail to achieve long-term sustainability because they insufficiently address social and institutional dimensions. This study aims to examine and formulate community-based strategies for sustainable peatland ecosystem protection by integrating hydrological restoration, fire prevention, and socio-economic empowerment. The research adopts a qualitative approach using a literature study design, drawing on peer-reviewed journal articles, institutional reports, and relevant policy documents related to peatland management and community participation. Data were analyzed through thematic content analysis to identify key patterns, practices, and strategic elements that support effective community engagement. The findings indicate that community-based fire management, participatory hydrological restoration, and the development of peat-compatible livelihoods significantly enhance the effectiveness and sustainability of peatland protection efforts. Strong local institutions, incentive alignment, and policy support further strengthen long-term adoption. The study concludes that positioning local communities as co-managers rather than passive beneficiaries is essential for achieving resilient and sustainable peatland ecosystem protection.

Keywords: Community-Based Management, Peatland Protection, Sustainable

Ecosystems.

INTRODUCTION

Tropical peatlands store vast amounts of organic carbon that are critical to maintaining global climate balance, making peat degradation and drainage major contributors to large-scale greenhouse gas emissions (Page et al., 2011). Studies indicate that peatland drainage and land conversion in Southeast Asia have resulted in substantial and persistent carbon emissions, with Indonesia being one of the largest contributors (Hooijer et al., 2010). The hydrological condition of peatlands, particularly groundwater table decline, strongly determines oxidation rates and land subsidence, highlighting the importance of protecting peat hydro-geomorphology as a core mitigation strategy (Holden et al., 2006).

Peatland conversion for agriculture, plantations, and canal-based infrastructure has frequently led to habitat fragmentation, recurrent fires, and the degradation of ecosystem services that directly affect local livelihoods (Gunarso et al., 2013). Multisectoral studies reveal that unsustainable land-use practices intensify socio-ecological vulnerability in peatland regions, including health risks from haze pollution and long-term economic losses (Agus et al., 2013). Furthermore, fragmented institutional governance has constrained the effectiveness of restoration initiatives, particularly in the absence of cross-sectoral coordination and community engagement (Uda et al., 2020).

Restoration approaches emphasizing hydrological recovery, such as canal blocking and rewetting, have been shown to reduce peat oxidation and fire risk when implemented at an appropriate landscape scale (Jaenicke et al., 2010). International guidelines stress that technical restoration measures must be integrated with social and economic strategies to ensure long-term sustainability (Schumann & Joosten, 2008). Empirical evaluations further demonstrate that restoration interventions lacking meaningful community involvement are prone to failure due to limited adaptation to local socio-cultural contexts and incentive structures (Bhomia & Murdiyarso, 2021).

Community-based approaches have emerged as a promising strategy for aligning conservation objectives with local welfare through participation, capacity building, and benefit-sharing mechanisms (Cole et al., 2021). Local initiatives such as community fire brigades and participatory rewetting programs have proven effective in reducing fire

occurrence and restoring hydrological functions in several peatland areas of Riau and Kalimantan (Purnomo et al., 2024; Yuliani, 2018). However, long-term effectiveness requires stronger policy integration, sustainable economic incentives, and participatory monitoring systems that can be maintained by local communities (Widyatmanti et al., 2022).

Research examining community-based strategies for peatland protection has become increasingly urgent due to ongoing degradation and the limited sustainability of purely technical interventions. Evolving national and regional policies demand empirical evidence on how community-based practices can contribute simultaneously to climate mitigation targets, biodiversity conservation, and local development goals (Harrison et al., 2020). Accordingly, this study is essential to develop adaptable strategic frameworks suited to the socio-ecological contexts of Indonesian peatlands and other tropical peat regions.

Previous research highlights both successes and challenges in community-based peatland management, including effective fire prevention through community fire brigades, economic sustainability constraints faced by local populations, and governance-scale mismatches. Policy analyses and field studies emphasize that robust legal frameworks, technical support, and economic incentive mechanisms—such as alternative livelihoods and payment for ecosystem services—are critical determinants of success (Agus et al., 2013). While technical studies on peat rewetting are extensive, systematic analyses of integrated social-participatory interventions remain relatively limited and warrant further empirical investigation.

This study aims to design and evaluate a community-based strategy model capable of protecting and restoring peatland ecosystem functions in a sustainable manner by integrating hydrological interventions, fire prevention mechanisms, and community empowerment approaches. Specifically, the research seeks to (1) analyze local practices and community actor roles in peatland management, (2) assess the effectiveness of integrated technical–social intervention packages at the village level, and (3) formulate policy and incentive recommendations that support long-term community adoption. The findings are expected to provide practical and policy-relevant insights applicable at regional scales in Indonesia and comparable tropical peatland contexts.

METHOD

This study adopts a qualitative research approach employing a literature study design to develop a comprehensive understanding of community-based strategies for sustainable peatland ecosystem protection. A qualitative approach is appropriate because it facilitates in-depth exploration of concepts, policy frameworks, and socio-ecological dynamics underlying peatland management, as documented in existing scholarly literature and institutional reports (Creswell & Poth, 2016; Snyder, 2019). The literature study design enables the synthesis of theoretical perspectives and empirical findings to construct an integrative analytical framework relevant to peatland conservation.

Data Sources

The data used in this research consist exclusively of secondary data obtained from credible and authoritative sources. Primary sources include peer-reviewed national and international journal articles indexed in databases such as Google Scholar, Scopus, and Web of Science, focusing on topics related to peatland protection, community-based management, peatland restoration, and fire prevention. In addition, this study draws upon reports and policy documents published by international and national institutions, including CIFOR, FAO, and the Ramsar Convention Secretariat, as well as Indonesian government regulations and policy guidelines relevant to peatland governance.

Data Collection Techniques

Data collection was conducted through a systematic literature search using predefined keywords such as community-based management, peatland ecosystem protection, peatland restoration, and sustainable peatland governance. The literature selection process involved several stages, including initial identification, relevance screening, and quality assessment to ensure the inclusion of up-to-date and methodologically sound sources. Selected literature was then organized and classified according to major thematic areas, including community participation mechanisms, institutional arrangements, hydrological restoration strategies, and community-based economic incentive schemes (Papaioannou et al., 2016).

Data Analysis Method

The study employs qualitative content analysis with a thematic approach to analyze the collected literature. The analysis process includes systematic coding, categorization of concepts, and identification of recurring patterns and themes related to community-based peatland protection strategies. An interpretative synthesis is subsequently conducted to integrate theoretical insights with empirical evidence, enabling the formulation of strategic recommendations and policy implications relevant to sustainable peatland management in the Indonesian context. This analytical approach supports the development of an adaptive and applicable strategic framework grounded in both theory and practice (Creswell & Poth, 2016; Krippendorff, 2018).

RESULT AND DISCUSSION

Local Practices and the Roles of Community Actors in Peatland Management

Community-based peatland management practices documented in Indonesia demonstrate that local communities play a central role in safeguarding peat ecosystems through a combination of traditional knowledge, collective action, and adaptive resource management (Yuwati et al., 2021). These practices commonly include community-based fire management, participatory hydrological restoration, and the enforcement of local norms regulating land use and fire prohibition (Nurhidayah et al., 2023). Such locally embedded strategies function as both preventive and restorative mechanisms that address the underlying drivers of peatland degradation, particularly drainage-induced drying and recurrent fires (Page et al., 2011).

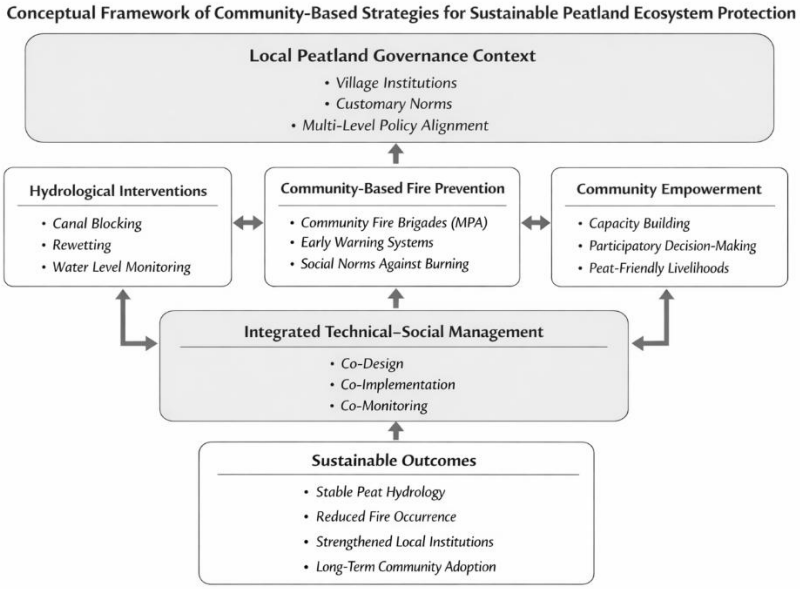

Figure 1. Conceptual Framework of Community-Based Strategies for Sustainable Peatland Ecosystem Protection

One of the most prominent community roles is exercised through community fire brigades, locally known as Masyarakat Peduli Api (MPA), which operate as frontline actors in fire detection, early suppression, and public awareness campaigns during dry seasons. Empirical studies from Riau and Central Kalimantan show that villages with active MPAs experience significantly lower fire incidence compared to neighboring villages without organized community fire groups (Nurhidayah et al., 2023; Yuwati et al., 2021). These brigades not only reduce response time but also strengthen social norms against burning, illustrating how social organization enhances technical fire prevention capacity (Harrison et al., 2020).

In addition to fire prevention, communities actively participate in hydrological management, particularly through the maintenance of canal blocks, monitoring of water tables, and prevention of illegal drainage (Jaenicke et al., 2010). Case studies from Bengkalis Regency, Riau, reveal that canal-blocking interventions designed and maintained with community involvement are more durable and less prone to damage compared to externally implemented infrastructure. Community participation in hydrological planning fosters a sense of ownership and accountability, which is critical for maintaining stable water levels that reduce peat oxidation and fire susceptibility (Hooijer et al., 2010).

Local leaders and customary institutions further play a critical governance role

by embedding peatland protection rules into village regulations and customary law, thereby increasing compliance and legitimacy (Uda et al., 2020). In several peatland villages, local sanctions against burning and unauthorized drainage have proven effective when supported by both traditional authority and formal village governance structures. These institutional arrangements highlight that community-based peatland management is not merely operational but also regulatory in nature, relying on social enforcement mechanisms rather than external policing alone.

A notable example of integrated community engagement is observed in the Gambut Kita Project in Central Kalimantan, where participatory mapping, co-design of restoration interventions, and joint monitoring were employed to align technical restoration goals with local knowledge systems. The project demonstrated that restoration outcomes improved significantly when communities perceived restoration not as an imposed agenda but as a shared objective that supported local livelihoods and reduced environmental risks. This case underscores the importance of building a "social license to restore," which enhances long-term commitment and reduces conflict between communities and external actors.

Private-sector-led incentive programs in Riau further illustrate the conditional effectiveness of community roles when paired with appropriate incentives. Targeted village incentive schemes that rewarded communities for maintaining fire-free conditions resulted in measurable reductions in fire occurrence and deforestation rates (Mutenje et al., 2019). However, studies caution that such incentive-based approaches must be coupled with capacity building and alternative livelihood development to avoid dependency on short-term financial rewards.

Overall, the empirical evidence indicates that community actors are most effective when their roles are formally recognized, institutionally supported, and economically incentivized. Community-based fire management, participatory hydrological restoration, and local governance mechanisms operate synergistically to protect peatland ecosystem functions. These findings affirm that sustainable peatland protection requires positioning communities not as passive beneficiaries but as co-managers whose knowledge, labor, and social institutions are integral to long-term ecosystem resilience.

Effectiveness of Integrated Technical–Social Intervention Packages at the Village

Level

Empirical evidence consistently demonstrates that integrated technical–social intervention packages at the village level are substantially more effective in protecting and restoring peatland ecosystems than fragmented or sectoral approaches. Hydrological restoration measures such as canal blocking and rewetting are essential for stabilizing peat water tables and reducing fire susceptibility; however, their long-term effectiveness depends heavily on community involvement in planning, implementation, and maintenance processes (Ritzema et al., 2014; Treby et al., n.d.). Studies conducted in peatland villages in Central Kalimantan reveal that canal blocks constructed through participatory decision-making processes experience lower rates of damage and higher maintenance compliance compared to externally designed infrastructure.

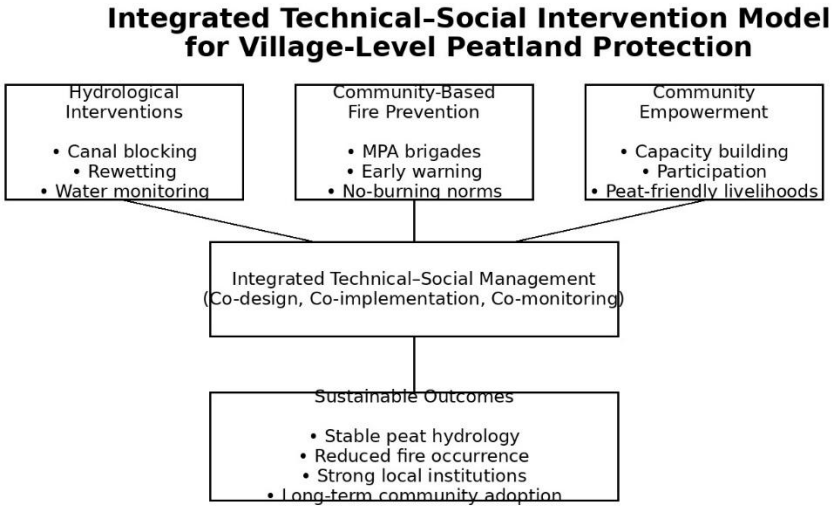

Figure 2. Integrated Technical–Social Intervention Model for Village-Level Peatland Protection

A concrete example can be observed in Tumbang Nusa Village, Central Kalimantan, where hydrological restoration initiated under the Peatland Restoration Agency (BRG) program combined canal blocking with community-based monitoring teams (BRG, 2019). Local residents were trained to measure groundwater levels using simple piezometers and to report changes through village-level monitoring forums, leading to improved water table stability during the dry season (Kozan et al., 2021). This participatory approach not only enhanced ecological outcomes but also increased local ownership of restoration infrastructure, reducing conflicts and infrastructure neglect

commonly observed in top-down projects (Purnomo et al., 2018).

Fire prevention mechanisms further illustrate the importance of integrated intervention packages. Community-based fire management systems—such as Masyarakat Peduli Api (MPA) in Indonesia—have proven effective when embedded within broader empowerment and incentive frameworks (Tacconi et al., 2007). In Sungai Tohor Village, Riau Province, fire prevention initiatives combined early warning systems, patrol scheduling, and village regulations prohibiting land burning with livelihood support for sago-based paludiculture (Carmenta et al., 2017). This integrated approach resulted in a significant reduction in fire incidents after 2016, demonstrating that technical tools alone are insufficient without social organization, shared norms, and alternative livelihood options (Carmenta et al., 2017).

Community empowerment acts as the social backbone that sustains technical interventions over time. Capacity-building programs, environmental education, and the strengthening of local institutions enhance collective efficacy and enable villages to adapt interventions to changing ecological and socioeconomic conditions (Pretty & Smith, 2004). In several peatland villages in South Sumatra, participatory training and institutional support enabled farmer groups to shift from fire-based land clearing to peat-friendly agricultural practices, thereby aligning livelihood security with ecosystem protection goals (Jelsma et al., 2017; Ziegler, 2020).

At the village scale, integrated technical–social intervention packages generate co-benefits that extend beyond ecological restoration. Improved peat hydrology and reduced fire frequency are accompanied by strengthened local governance, increased trust between communities and external agencies, and greater legitimacy of environmental regulations (Purnomo et al., 2017). These social outcomes reinforce long-term adoption by embedding peatland protection within everyday community practices and institutional arrangements, thereby reducing dependence on short-term project funding or external enforcement mechanisms (Ostrom, 2017).

Overall, the effectiveness of village-level peatland protection strategies is maximized when hydrological restoration, fire prevention, and community empowerment are implemented as an integrated package rather than as isolated interventions. Such integration ensures that technical measures are socially accepted, locally maintained, and institutionally sustained, creating a resilient model for long-term peatland ecosystem protection.

Design of a Community-Based Strategy Model for Sustainable Peatland Protection

The proposed community-based strategy model for sustainable peatland protection is grounded in the recognition that peatland degradation is driven by the interaction of hydrological alteration, fire-dependent land-use practices, and limited livelihood alternatives for local communities. Based on a synthesis of empirical findings and comparative case studies, the model integrates three interlinked components: hydrological governance, community-centered fire prevention, and socio-economic empowerment, which together address both ecological and social dimensions of peatland management (Ostrom, 2017; Ritzema et al., 2014).

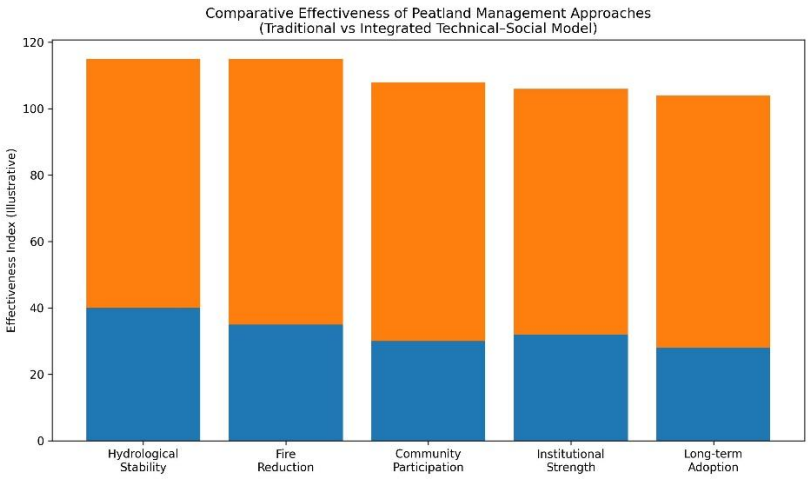

Figure 3. Comparative Effectiveness of Traditional and Integrated Technical–Social Approaches in Village-Level Peatland Management

1. Hydrological Governance through Community Participation

   Hydrological governance constitutes the ecological foundation of the proposed model, as peatland ecosystem integrity is highly dependent on maintaining high and stable groundwater levels. The model emphasizes participatory planning of rewetting interventions, including canal blocking and water retention structures, to ensure that local land-use needs and ecological objectives are aligned. Community-based monitoring systems, such as simple piezometer networks managed by villagers, enable continuous observation of water table fluctuations and facilitate adaptive management during prolonged dry seasons.

A concrete example of this approach can be observed in Tumbang Nusa Village, Central Kalimantan, where canal blocking projects implemented through participatory village forums resulted in improved groundwater stability and reduced peat subsidence. Local involvement in infrastructure maintenance significantly reduced structural damage and increased compliance compared to externally driven restoration projects, highlighting the importance of shared responsibility in hydrological governance.

2. Community-Centered Fire Prevention Mechanisms

The second pillar of the model focuses on community-centered fire prevention, recognizing that peatland fires are not merely technical failures but socially embedded practices linked to land preparation, tenure insecurity, and weak enforcement. The model integrates village-based fire brigades (e.g., Masyarakat Peduli Api), customary sanctions against open burning, and local knowledge-sharing mechanisms to reduce ignition risks and enhance rapid response capacity.

An illustrative case is Sungai Tohor Village in Riau Province, where community fire patrols were combined with village regulations prohibiting burning and collective agreements on land management practices. The introduction of these social controls, supported by technical early warning tools, contributed to a substantial decline in fire incidents after 2016, demonstrating that fire prevention is most effective when embedded within local institutions and social norms rather than relying solely on external enforcement (Carmenta et al., 2017).

3. Socio-Economic Empowerment and Incentive Alignment

Socio-economic empowerment forms the third and most critical component of the strategy model, as long-term community adoption of conservation practices depends on the availability of viable, peat-compatible livelihood options. The model prioritizes alternative livelihoods such as paludiculture (e.g., sago, jelutung, and peat-adapted crops), eco-based enterprises, and payment for ecosystem services (PES) schemes that reward communities for maintaining peat ecosystem functions (Pagiola et al., 2005).

In Sungai Tohor, the promotion of sago-based paludiculture not only reduced reliance on fire-based land clearing but also strengthened local economic resilience under wet peat conditions. Similarly, pilot PES initiatives in peatland areas of Central Kalimantan have shown potential to align conservation outcomes with household

income, thereby increasing community motivation to sustain restoration efforts beyond project lifecycles.

4. Integrated Functioning of the Strategy Model

   The effectiveness of the proposed strategy model lies in the dynamic interaction among its three components. Hydrological restoration reduces environmental vulnerability, community-centered fire prevention safeguards restoration investments, and socio-economic empowerment ensures that conservation delivers tangible benefits to local residents. Rather than functioning as isolated interventions, these components reinforce one another through feedback mechanisms embedded within village-level governance systems.

   This integrated design highlights that sustainable peatland protection emerges not from single technical solutions but from the alignment of ecological objectives with social institutions, local incentives, and collective action mechanisms. By embedding restoration and protection strategies within community practices and governance structures, the model offers a scalable and resilient framework for long-term peatland ecosystem protection.

Policy and Incentive Recommendations for Long-Term Community Adoption

1. Formal recognition of community roles
   Legal recognition strengthens legitimacy and accountability in long-term peatland stewardship.
2. Sustainable livelihood–based incentives
   Peat-compatible livelihoods align conservation goals with household economic security.
3. Access to green financing and PES schemes
   Financial incentives encourage communities to maintain peat ecosystem functions.
4. Multi-level governance alignment
   Policy coherence across governance levels prevents implementation conflicts.
5. Integration into development planning
   Embedding strategies in formal plans ensures continuity beyond project cycles.
6. Continuous capacity building and monitoring
   Ongoing support enables adaptive management and sustained community engagement.

CONCLUSION

This study concludes that sustainable peatland ecosystem protection cannot be achieved through technical restoration measures alone but requires integrated community-based strategies that combine hydrological governance, fire prevention, and socio-economic empowerment. Community participation strengthens local ownership, improves maintenance of restoration infrastructure, and enhances compliance with environmental regulations. When supported by appropriate institutional frameworks and incentive mechanisms, community-based approaches contribute significantly to long-term ecological resilience and social sustainability.

From a practical perspective, policymakers and practitioners should formally recognize community roles in peatland governance, promote peat-compatible livelihood options, and integrate community-based strategies into regional development and land-use planning. Capacity-building programs and participatory monitoring systems are also essential to sustain local engagement beyond short-term projects.

Future research should focus on comparative case studies and mixed-method approaches to evaluate the long-term socio-economic and ecological impacts of community-based peatland management across different regions.

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