SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 5067-5077
Open Access. Online & Print

DOI: 10.5281/zenodo.19113490

KEY DRIVERS OF SUSTAINABLE PEATLAND CONSERVATION FOREST GOVERNANCE IN RIAU, INDONESIA

Zulhendri[1*], Suwondo[1], Thamrin[2], Ali Yusri[3]

[1]Doctor of Environmental Science, Postgraduate Program, Universitas Riau, Indonesia
[2]Department of Marine Sciences, Fisheries and Marine Sciences Faculty, Universitas Riau, Indonesia
[3]Department of Government Science, Faculty of Social and Political Sciences, University of Riau, Indonesia

Received: 06/02/2026
Accepted: 05/03/2026

Corresponding Author: Zulhendri (zulhendrinazaruddin@gmail.com)

ABSTRACT

Degradation of conservation forest areas within peat ecosystems in Riau Province continues to intensify due to ongoing deforestation, forest degradation, and mounting land-use pressures. This study examines ecological conditions, land cover dynamics, damage typologies, and key constraints affecting management success in Bukit Batu Wildlife Sanctuary, Zamrud National Park, and Sungai Dumai Nature Tourism Park using spatial analysis, field observations, interviews, focus group discussions (FGDs), and Structural Equation Modeling (SEM). The findings reveal that 84.60% of the landscape remains covered by secondary swamp forest, while primary swamp forest persists only in limited fragments. Between 1990 and 2023, approximately 18,832.52 ha of forest cover were lost, corresponding to an average deforestation rate of 570.68 ha per year. Two principal forms of damage were identified—degradation and outright deforestation. SEM results indicate that economic ($\beta = 0.71$), policy ($\beta = 0.68$), social ($\beta = 0.44$), ecological ($\beta = 0.41$), and sustainable development factors ($\beta = 0.34$) significantly shape management effectiveness, with a Q^2 value of 96%, underscoring the critical importance of strengthened governance, enhanced community economic capacity, integrated policy frameworks, and multi-stakeholder collaboration to achieve sustainable peat conservation forest management.

KEYWORDS: Peat Ecosystem, Conservation Area, Deforestation. Forest Management, Limiting Factors for Management Success.

1. INTRODUCTION

Environmental damage in conservation forest areas within peat ecosystems has become a strategic issue in Riau Province. Massive deforestation, fires, and land conversion have threatened the ecological and hydrological functions of these areas and resulted in biodiversity loss (Lam et al., 2022; Suwondo et al., 2023) . Peat forests, which should support life, are instead being degraded due to development pressures (Syahza et al., 2020). This situation is exacerbated by increased greenhouse gas emissions resulting from the conversion of peatlands to plantations, settlements, and infrastructure (Cooper et al., 2020)..

Conservation forest areas in Riau's peatlands include wildlife sanctuaries, national parks, and nature tourism parks spread across various regions [5]. These areas play a vital role in supporting the Sustainable Development Goals (SDGs), particularly SDG 15, which emphasizes the sustainable management of terrestrial ecosystems. However, on the ground, management implementation remains far from optimal, as evidenced by the persistently high rate of damage and the failure to achieve revegetation and customary forest recognition targets [Bappeda, 2022; Haryanto et al., 2023). This situation is further complicated by weak institutions, overlapping regulations, and limited oversight and budget (Putri et al., 2021). The lack of synchronization between conservation policies, community empowerment, and regional development has resulted in a lack of support for the sustainability of forest areas. For example, community engagement strategies through social forestry have not been optimally implemented, even though community-based approaches have been proven to increase conservation effectiveness (Fatimah et al., 2023).

In a social and economic context, communities surrounding forest areas remain highly dependent on land, but limited access to legal resources makes them vulnerable to illegal activities such as encroachment (Surahman et al., 2017). Therefore, a comprehensive analysis of the socio-economic conditions and governance of the area is necessary to ensure that the strategies developed can simultaneously address local structural and cultural challenges. Considering this complexity, an in-depth study is essential to analyze the conditions and limiting factors influencing the successful management of conservation forest areas within peat ecosystems in Riau Province. This analysis is expected to form the basis for developing a more integrated, multidimensional, and evidence-based management strategy, in line with the direction of national and regional sustainable development policies [Pergub Riau, 2021; Perpres, 2022).

2. METHOD

2.1. Study Area

The research was conducted in Riau Province. Riau Province has an area of 89,935.90 km² and consists of 12 regencies/cities: Kuantan Singingi, Bengkalis, Dumai, Indragiri Hilir, Indragiri Hulu, Kampar, Pelalawan, Rokan Hilir, Rokan Hulu, Meranti Islands, Pekanbaru, and Siak. The research was conducted in 2024-2025. The focus of the research was conservation forest areas on peatlands in Riau Province.

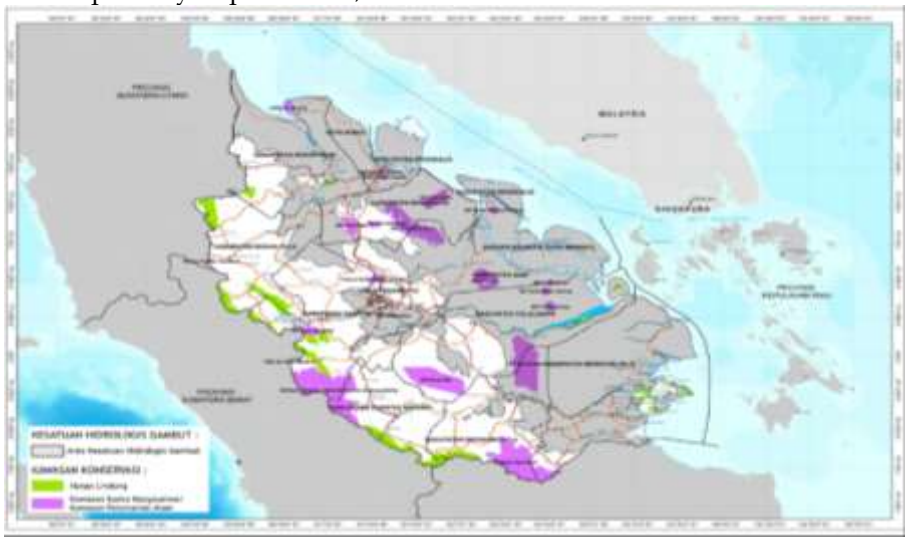

Figure 1: Map of Conservation Forest Areas On Peatlands In Riau Province.

The location of the research on forest areas in peatlands was determined by representing the

characteristics of the type of forest area management in peatlands. There are 4 very large conservation and protected forest areas on peatlands in Riau Province, namely: (1) Bukit Batu Wildlife Sanctuary in Bengkalis Regency, (2) Zamrud National Park in Siak Regency, (3) Sungai Dumai Nature Tourism Park in Dumai City. The determination of the location of the village for collecting socio-economic data in the field was determined by purposive random sampling which is located in the forest area management area in the 3 Regencies.

2.2. Procedure

Data collection was conducted to obtain primary and secondary data according to the research objectives. Primary data collection was conducted through field observation surveys, direct measurements, interviews, and focus group discussions (FGDs). Secondary data was collected through literature review, reviewing government environmental documents and other scientific articles. Ecological data consisted of the rate of forest cover conversion and the typology of damage to conservation forest areas in peat ecosystems, using: (1) a spatial analysis approach and (2) field observations. The analysis was conducted spatially using a Geographic Information System (GIS) in the form of ArcGIS 10.4.1

2.3. Data Analysis

The data obtained are data related to 6 reference variables of the GHRM concept (Table 1), namely 1. Green Recruitment & Selection, 2. Green Training & Development, 3. Green Performance Management & Appraisal, 4. Green Compensation, 5. Green Employee Empowerment & Participation, 6. Green Organizational Culture Management, 7. Environmental Awareness as the expected stimulus output through the implementation of GHRM, and 8. Existing conditions of PT. Angkasa Pura Indonesia's policies.

3. RESULT AND DISCUSSION

Data should be presented in tables or figures when feasible. There should be no duplication of data in tables and figures. Suficient and comprehensive data followed with some index of variation (e.g., SD, SE) and significance level (e.g., $P<0.01$) should be presented to give a complete information and allow the reader to interpret the results of the experiment. The text should explain or elaborate the tabular data, but numbers should not be repeated extensively within the text.

3.1. Condition Of Conservation Forest Areas in Peat Ecosystem

The implementation of Green Human Resource Management (GHRM) at PT. Angkasa Pura Indonesia is closely related to increasing employee environmental awareness (Figure 2), where sustainability-based recruitment, training, and reward practices encourage environmentally friendly behavior. GHRM integration can increase employee commitment to environmental issues through training and incentive programs that encourage active participation in sustainability practices (Renwick et al., 2013). At PT. Angkasa Pura, the implementation of policies such as waste reduction and energy efficiency has strengthened employee environmental awareness, in line with the findings of Yusoff et al. (2020) that GHRM is effective in building an environmentally conscious corporate culture. Thus, GHRM not only drives the company's environmental performance but also increases employee awareness and engagement in sustainable practices.

Table 1: Types Of Conservation Forest Areas (KSA And KPA) In Riau Province.

No	Area Management Typology	Type of Area	Characteristics of Land Typology	
			Non-Peatland	Peatland
A	**Nature Reserve Area**			
1	Nature Reserve (NR)	▪ NR Pulau Berkey	Y	
		▪ NR Bukit Bungkuk	Y	
2	**WILDLIFE RESERVE (WR)**	▪ WR Tanjung Padang		Y
		▪ WR Tasik Serkap		Y
		▪ WR PLG Sebanga	Y	
		▪ WR Bukit Rimbang Bukit Baling	Y	
		▪ WR Tasik Besar Serkap		Y
		▪ WR Tasik Belat		Y
		▪ WR Giam Siak Kecil		Y
		▪ WR Bukit Batu		Y
		▪ WR Kerumutan		Y
		▪ WR Balai Raja	Y	
B	**Nature Conservation Areas**			
1	National Parks (NP)	▪ NP Zamrud		Y

		▪ NP Bukit Tiga Puluh	Y	
		▪ NP Teso Nilo	Y	Y
2	Nature Tourism Park (NTP)	▪ NTP Sungai Dumai	Y	Y
		▪ NTP Buluh Cina	Y	

Information: Y = There is

The existence of Nature Reserve Areas (KSA) and Nature Conservation Areas (KPA) in Riau Province is not entirely located on peatland typology, but also includes mineral and mangrove lands (Rossita et al., 2021). However, conservation forest areas in the peat ecosystem in Riau are quite numerous, so their management needs to be optimal. Peat ecosystems have unique biophysical characteristics in the form of high organic and water content and have irreversible drying properties (Obeng et al., 2023), namely a condition where dried peat cannot absorb water again, resulting in total damage due to changes in properties from hydrophilic to hydrophobic Perdana et al., 2018). Examples of nature reserves in Riau are Bukit Batu Wildlife Reserve, while nature conservation areas are represented by Zamrud National Park and Dumai River Nature Tourism Park. KSA are areas with certain characteristics, both on land and water, which function to preserve biodiversity and as life support areas. Meanwhile, KPA has similar characteristics but is focused on protecting life support systems, preserving biodiversity, and utilizing resources sustainably.

3.2. Ecological Aspects of Conservation Forest Areas in Peat Ecosystem

a. Land cover conditions in conservation forest areas in peat ecosystems

Land cover conditions were analyzed to reveal patterns of land use activity within an area. The analysis was conducted spatially by comparing existing land cover conditions with the presence of conservation forest areas within peat ecosystems.

Table 2: Land Cover Conditions Within Conservation Forest Areas Within Peat Ecosystems in Riau Province.

No	Land Cover Types	Area (ha)	
		Area (ha)	%
1	Primary Swamp Forest	679.93	0.29
2	Secondary Swamp Forest	199,328.60	84.60
3	Plantation Forest	3.92	0.00
4	Swamp Scrub	18,773.85	7.97
5	Settlements	49.27	0.02
6	Plantations	3,236.00	1.37
7	Mining	1,040.05	0.44
8	Mixed Dryland Agriculture	318.36	0.14
9	Swamps	6,953.92	2.95
10	Open Land	1,387.89	0.59
11	Water Bodies	3,844.94	1.63
Total		**235,616.71**	**100.00**

Land cover analysis results indicate that most conservation forest areas within the peat ecosystem in Riau Province are still in secondary swamp forest cover (Giesen & Sari, 2018). This is evident from the 84.60% secondary swamp forest cover. The remainder has been converted to various uses, including settlements, plantations, mining, mixed dryland agriculture, and open land. Revealed that the challenge of managing conservation areas in Indonesia is the high rate of deforestation for various land use activities (Wu et al., 2020; Word et al., 2022). The most dominant land uses are agriculture and settlements, including in Riau Province. Based on remote sensing analysis techniques conducted in Riau Province, forest cover loss is caused by conversion to plantations, settlements, and open land (Santoso et al., 2022). The process of forest loss generally occurs gradually, with clearing for settlements, plantations, or other purposes through logging or burning (Shafitri et al., 2018; Austin et al., 2019).

Land cover changes also occurred at the three study sites. The complete data from the land cover analysis in Bukit Batu Wildlife Sanctuary, Zamrud National Park, and Sungai Dumai Natural Park are presented in Table 3. Land cover in the Bukit Batu Wildlife Sanctuary, Zamrud National Park, and Dumai River Nature Tourism Park shows that 85.12% of the area remains forested, dominated by secondary swamp forest, while only 0.06% of primary swamp forest remains. Land cover changes occur due to conversion to residential areas, plantations, mining, and open land, although conservation areas should be maintained in a

forested state according to their natural function. The purpose of conservation areas is to protect biodiversity habitats, namely primary and secondary forests (Morales et al., 2015). Primary forests are known as virgin forests (Maulana et al., 2019), while secondary forests grow after primary forest destruction due to human or natural activities (Nakita et al., 2022). Although secondary forests show disturbances, they are still rich in flora and fauna and can undergo natural succession to primary forests (Derroire et al., 2016).

Table 3: Land Cover Conditions in Bukit Batu Wildlife Sanctuary, Zamrud National Park, And Sungai Dumai Natural Park.

No	Land Cover Types	Area (ha)			Total (ha)	Total (%)
		WR Bukit Batu	NTP Sungai Dumai	NP Zamrud		
1	Primary Swamp Forest			34.51	34.51	0.06
2	Secondary Swamp Forest	20,486.53	71.20	27,739.04	48,296.76	85.12
3	Plantation Forest			3.74	3.74	0.01
4	Settlements		37.96		37.96	0.07
5	Plantations	76.14	971.16		1,047.30	1.85
6	Mining			1,040.05	1,040.05	1.83
7	Swamps		21.68		21.68	0.04
8	Open Land	236.68	384.44	28.00	649.12	1.14
9	Water Bodies	68.81		2,417.78	2,486.59	4.38
10	Swamp Scrubs	797.55	2,081.21	242.70	3,121.46	5.50
Total		**21,665.70**	**3,567.64**	**31,505.83**	**56,739.17**	**100.00**

b. The rate of land cover conversion in conservation forest areas in peat ecosystems

The results of the land cover analysis for 33 years (1990–2023) show a decrease in forest area in conservation forest areas in peat ecosystems in Riau Province. Of the total 235,616.71 ha, in 1990, 218,844.96 ha were still forested, but in 2023 only 200,012.44 ha remained with forested land cover. Based on the land cover data above, it is known that during the period 1990–2023, conservation forest areas in peat ecosystems in Riau Province have lost as much as 18,832.52 ha of forested land cover. If analyzed by coverage period, it is estimated that the rate of forest conversion in conservation forest areas in peat ecosystems in Riau Province is 570.68 ha per year. This value indicates the rate of deforestation that has occurred so far. Deforestation is a process of loss of natural forest cover for various reasons ranging from logging for the utilization of forest products or changing forest functions to various land use activities. Several human activities that commonly trigger deforestation, including logging, agricultural expansion, and the timber industry, have resulted in the loss of valuable forest areas (Hanna et al., 2020).

Forest cover conversion was also evident at three research sites: Bukit Batu Wildlife Sanctuary, Zamrud National Park, and Sungai Dumai Natural Park. Data from the land cover change analysis at these locations are presented in Table 4. The analysis shows that conversion or deforestation of forests to non-forest areas has occurred in all conservation forest areas, namely Bukit Batu Wildlife Sanctuary, Zamrud National Park, and Sungai Dumai Natural Park, although the rate of conversion varies by area. During the 1990–2023 period, the highest rate occurred in Sungai Dumai Natural Park at 69.95 ha/year, followed by Zamrud National Park at 39.75 ha/year, and Bukit Batu Natural Park at 16.32 ha/year, encompassing conversion from primary and secondary swamp forests. This condition indicates that high deforestation challenges occur across all types of conservation area management. Land conversion in peat ecosystems has significant environmental impacts, including reduced biodiversity and damage to the physical, chemical, and biological properties of peat (Anhar et al., 2022). These impacts include a decline in the physical quality of peat, increased decomposition and subsidence, and disruption of the hydrological cycle, which causes peat to dry out and become flammable (Dohong et al., 2018). Furthermore, because peat is a large carbon store, deforestation and fires can trigger large amounts of carbon dioxide emissions and increase greenhouse gas emissions (Ribeiro et al., 2020), including the release of methane which is much greater than other land types (Graham et al., 2022).

Table 4: Rate Of Peat Swamp Forest Cover Conversion in Bukit Batu Wildlife Sanctuary, Zamrud National Park, And Sungai Dumai Natural Park.

No	Types of Conversion	Area (ha)		Fungction Change (ha)	Conversion Rate (ha/Year)
		1990	2023		
A	**Bukit Batu**				
1	Primary Swamp Forest				
2	Secondary Swamp Forest	21,025.05	20,486.53	-538.52	-16.32
3	Non-Forest	640.65	1,179.17	538.52	16.32
B	**Zamrud National Park**				
1	Primary Swamp Forest	18,733.62	34.51	-18,699.11	-566.64
2	Secondary Swamp Forest	10,351.79	27,739.04	17,387.25	526.89
3	Non-Forest	2,420.42	3,732.28	1,311.86	39.75
C	**Dumai River National Tourism Park**				
1	Primary Swamp Forest				
2	Secondary Swamp Forest	2,379.59	71.20	- 2,308.40	-69.95
3	Non-Forest	1,188.05	3,496.44	2,308.40	69.95
D	**Total**				
1	Primary Swamp Forest	18,733.62	34.51	-18,699.11	-566.64
2	Secondary Swamp Forest	33,756.43	48,296.76	14,540.33	440.62
3	Non-Forest	4,249.12	8,407.90	4,158.78	126.02

C. Typology of damage to conservation forest areas in peat ecosystems

The analysis was conducted based on land cover change patterns before and after utilization or conversion. The results of the analysis identifying damage typologies in conservation forest areas in peat ecosystems are presented below. Based on the analysis, there are two typologies of damage to conservation forest areas in peat ecosystems due to forest conversion. The first typology is forest degradation, which is a decline in land cover quality where primary forest is converted into secondary forest or remains primary but with reduced vegetation, which is categorized as low to moderate damage depending on the intensity of logging. The second typology is deforestation, which is the conversion of primary and secondary forests into non-forest land, whether productive such as plantations, settlements, agriculture, fishponds, and transmigration (Suwondo et al., 2018), or non-productive such as shrubs, swamps, and open land due to prolonged land disuse (Carmenta et al., 2017). These changes are exacerbated by the many actors at the site level with interests in land and unclear ownership. Plantation activities are the main driver of change, even faster than settlement expansion (Numata et al., 2022).

The results of the field survey also identified various factors that trigger accelerated damage to the area, namely: (1) open access for the community via unsupervised roads or rivers, (2) unrestored fires, (3) increasing demand for community land for agriculture and housing, (4) uncertainty in the transition of area management, and (5) limited supervision and security of the area. This condition is very real, especially in peat areas that directly border residential areas, where pressure on conservation land is increasing.

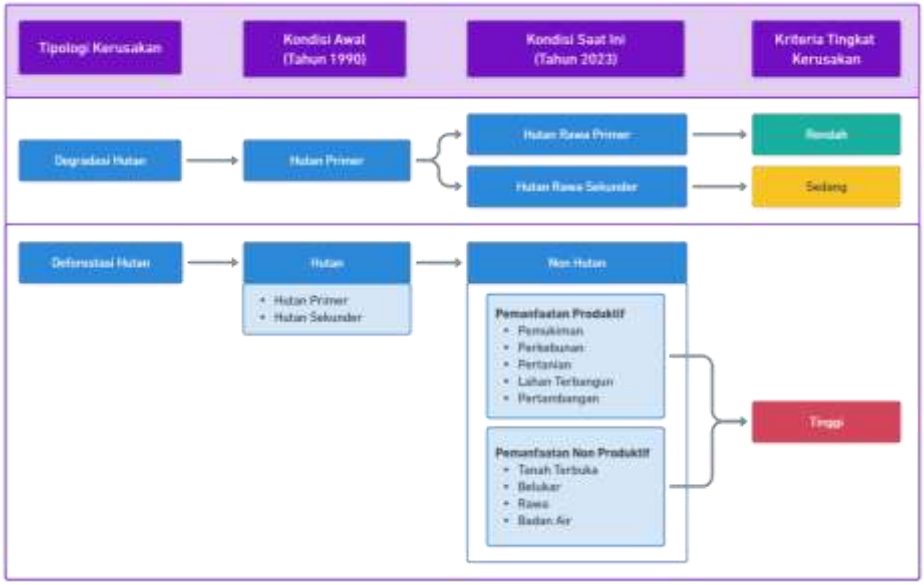

Figure 2: Typology Of Damage To Conservation Forest Areas In Peat Ecosystems.

4. LIMITING FACTORS FOR THE SUCCESS OF CONSERVATION FOREST AREA MANAGEMENT IN PEAT ECOSYSTEM

Based on the results of the PLS analysis (Figure 4), a Q2 value of 96% was obtained. This coefficient indicates that the strength of the analyzed structural model is 96% explained by the PLS structural modeling created, while the remaining 4% is explained by other variables, so the model's prediction value is highly relevant and accurate. Ecological variables can directly influence conservation forest management with a coefficient value of 0.41*** or 41% and are highly significant. This means that ecological variables, indicated by the lower rate of land conversion and damage typology, will increasingly ensure the success of conservation forest management. The less conservation land that is converted, the better the success of forest management (Bennett et al., 2009). Likewise, a lower damage typology will ensure the success of sustainable forest management (Barbati et al., 2007). However, in addition to influencing conservation forest management, ecological variables also have very significant interactions with other variables, such as social variables with an interaction strength of 51%, with the economy at 52%, with policy at 45%, and with sustainable development at 40%.

Social variables have a direct influence on conservation forest management with a coefficient of β = 0.44** or 44%. This indicates that the stronger community perceptions and social institutions, the higher the likelihood of successful conservation forest management. Community participation in conservation has been shown to increase the effectiveness of resource management programs (Rampheri et al., 2021). Furthermore, social variables also significantly influence the economy with a value of 32%, a very significant influence on policy with a value of 50%, and a significant influence on sustainable development with a value of 31%. This means that conservation sustainability is determined not only by biophysical factors but also by social legitimacy through trust, collaboration, and community involvement in decision-making (Stupak et al., 2021). Improved community welfare and participation boost the local economy (Lukkarine et al., 2005).

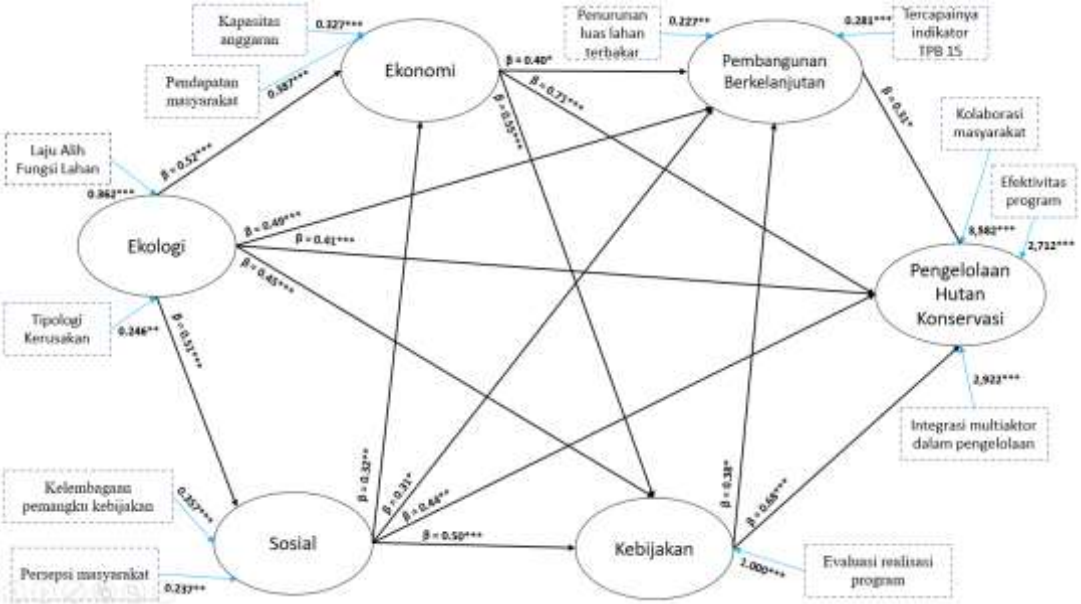

*Figure 3: SEM Model of Conservation Forest Management. B = Strength of Variable Interaction, *) Sig = 0.05-0.1; **) Sig = 0.01-0.05; ***) Sig = < 0.01; Solid Line Indicates Direct and Significant Interaction Between Variables; Q2 Model Value = 96%.*

Economic variables significantly influence conservation forest management with a coefficient of β = 0.71*** or 71%. This suggests that the better the community's economic conditions, as indicated by increased income and budget capacity, the more effective conservation forest management will be. This is consistent with (Wunder et al., 2021) research, which states that the economic well-being of communities surrounding conservation areas can reduce dependence on forest resource exploitation. Furthermore, economic variables also significantly interact with sustainable development (β = 0.40*) and with policy (β = 0.55***). This interaction indicates that environmentally based economic development can support ecosystem sustainability and the achievement of sustainable development goals

(Barbier, 2019).

The policy variable has a very strong influence on conservation forest management, with a coefficient of β = 0.68*** or 68%. This means that the better the quality of the policy, particularly through program implementation evaluation instruments, the greater the effectiveness of conservation forest management. These results align with (Ostrom et al., 2009), who emphasized that natural resource governance based on clear rules, monitoring, and evaluation can improve management sustainability. Policies are also influenced by social (β = 0.50***), ecological (β = 0.45***), and sustainable development (β = 0.38*) variables, confirming that conservation policies must be cross-dimensional to be adaptive to ecological, social, and economic challenges.

The sustainable development variable significantly influences conservation forest management with a coefficient of β = 0.34* or 34%. This means that the higher the achievement of sustainable development indicators (such as reducing burned land area and achieving SDG 15), the higher the effectiveness of conservation forest management. Success of sustainable development is largely determined by the protection of terrestrial ecosystems and the integration of environmental policies (Tan et al., 2019). Furthermore, sustainable development is also closely linked to ecology (β = 0.40*), economics (β = 0.40*), and social (β = 0.31*), demonstrating the importance of multidimensional synergy to ensure conservation sustainability.

In general, economic factors (71%), such as budget capacity and community income, and policy factors (68%), such as program implementation evaluation, are the primary determinants of successful conservation forest management, as indicated by community collaboration, program effectiveness, and multi-actor integration in management. Economic factors, such as budget capacity and community income, and policy factors, such as program implementation evaluation, are key determinants of successful conservation forest management because they provide the financial and governance foundations that enable effective and sustainable program implementation (Cinner et al., 2019). Adequate budget capacity ensures resources for conservation activities, monitoring, and empowering local communities, while increasing community income can reduce dependence on forest resource exploitation and encourage active participation in conservation (Wunder et al., 2015). Furthermore, program implementation evaluation is a crucial instrument in adaptive policy, enabling objective assessment of intervention effectiveness, transparency of budget use, and evidence-based policy improvements [Liu et al., 2014]. Thus, the combination of stable economic support and adaptive evaluative policies forms a synergistic mechanism that enhances the effectiveness of conservation forest management.

4. CONCLUSION

This study shows that the condition of conservation forest areas in peat ecosystems in Riau Province is in a vulnerable situation due to the high rate of land conversion, forest degradation, and conversion to various forms of non-forest use. Primary swamp forests have almost disappeared, while secondary swamp forests are under constant pressure. Over the past 33 years, the conservation area has lost more than 18 thousand hectares of forest cover with a deforestation rate reaching 570.68 hectares per year. Two typologies of damage were identified, namely forest degradation and deforestation, triggered by access opening, recurrent unrestored fires, community land needs, unclear management of the area, and weak supervision. Through SEM modeling, it was found that the success of conservation area management is strongly influenced by five main factors: ecology, social, economy, policy, and sustainable development, with a model strength reaching 96%. Economic and policy factors emerged as the strongest determinants of management effectiveness, while social and ecological factors strengthened sustainability through community participation and the biophysical conditions of the area. Thus, successful management of conservation forest areas in peat ecosystems requires an integrated approach through strengthening adaptive policies, improving community welfare, optimizing conservation budgets, and implementing cross-actor strategies based on sustainability indicators. Damage mitigation efforts must be directed at preventing deforestation, restoring peatlands, improving monitoring, and integrating conservation programs with regional development.

REFERENCES

Anhar, I.P, Rina M., Sita R. (2022). The Impact of Forest and Peatland Fires on Humans and the Environment (Case Study: Bunsur Village, Sungai Apit District, Siak Regency, Riau Province). *Journal of Communication Science and Community Development*, 6 (1): 75-85. [in Indonesia]

Austin, K., Schwantes, A., Gu, Y., & Kasibhatla, P. (2019). What causes deforestation in

Indonesia? *Environmental Research Letters*, 14. https://doi.org/10.1088/1748-9326/aaf6db.

Barbati, A., Corona, P., & Marchetti, M. (2007). A forest typology for monitoring sustainable forest management: the case of European forest types. *Plant Biosystems*, *141*(1), 93-103.

Barbier, E. B. (2019). *The Concept of Sustainable Economic Development*. *Environmental Conservation*, 14(2), 101–110.

Bennett, A. F., Haslem, A., Cheal, D. C., Clarke, M. F., Jones, R. N., Koehn, J. D., ... & Yen, A. L. (2009). Ecological processes: a key element in strategies for nature conservation. *Ecological Management & Restoration*, *10*(3), 192-199.

Carmenta R., Zabala A., Daeli W., Phelps J. (2017). erceptions across scales of governance and the Indonesian peatland fires. *Global Environmental Change* 46: 50-59

Cinner, J. E., Huchery, C., MacNeil, M. A. (2019). Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, 9, 468–47

Cooper, H. V., Evers, S., Aplin, P., Crout, N., Dahalan, M. P. B., & Sjogersten, S. (2020). Greenhouse gas emissions resulting from conversion of peat swamp forest to oil palm plantation. *Nature communications*, *11*(1), 407.

Derroire, G., Balvanera, P., Castellanos-Castro, C., Decocq, G., Kennard, D., Lebrija-Trejos, E., Leiva, J., Odén, P., Powers, J., Rico-Gray, V., Tigabu, M., & Healey, J. (2016). Resilience of tropical dry forests – a meta-analysis of changes in species diversity and composition during secondary succession. *Oikos*, 125, 1386-1397. https://doi.org/10.1111/oik.03229.

Dohong, A., Abdul Aziz, A., & Dargusch, P. (2018). A review of techniques for effective tropical peatland restoration. *Wetlands*, *38*, 275-292.

Fatimah, Y.A., Prasojo, Z.H., Smith, S.W., Rahman, N.E.B., Wardle, D.A., Chong, K.Y., Saad, A., Lee, J.S. 2023. *Multi-level actor-network: Case of Peatland programs in a Riau Village, Indonesia (1974-2020)*. Geoforum, 145: 103829.

Giesen, W., & Sari, E. N. (2018). Tropical peatland restoration report: the Indonesian case. *Berbak Green Prosperity Partnership, MCA-Indonesia, Jakarta*.

Governor's Regulation. (2021). *Riau Governor's Regulation Number 9 of 2021 concerning Green Riau*. Riau

Graham, L., Applegate, G., Thomas, A., Ryan, K., Saharjo, B., & Cochrane, M. (2022). A Field Study of Tropical Peat Fire Behaviour and Associated Carbon Emissions. *Fire*. https://doi.org/10.3390/fire5030062.

Hanna D.E., Ciara R.H., Elena M.B. (2020). Effects of land use, cover, and protection on stream and riparian ecosystem services and biodiversity. *Conservation Biology*, 34 (1): 244–55.

Haryanto, R., Juandi., Siregar, S.H., Suwondo. (2023). 30 years trend of peatland utilization in Riau Province. *IOP Conf. Series: Earth and Environmental Science*, 1230 (2023): 012066, doi:10.1088/1755-1315/1230/1/012066

Lam, S., Goodrich, J., Liang, X., Zhang, Y., Pan, B., Schipper, L., Sulaeman, Y., Nelson, L., Chen, D. 2022. Mitigating Soil Greenhouse-Gas Emissions from Land-Use Change in Tropical Peatlands. *Frontiers in Ecology and the Environment*, 2497: 1-9.

Liu, Y., Li, J., & Yang, Y. (2014). *Strategic adjustment of land use policy under the economic transformation*. **Sustainability**, 6(4), 1946–1961. [DOI: 10.3390/su6041946]

Lukkarinen, M. (2005). Community development, local economic development and the social economy. *Community Development Journal*, 40(4), 419-424.

Maulana A., Suryanto, P., Widiyatno., Faridah E., Suwignyo B. (2019). The Dynamics of Succession of Vegetation in the Post-Shifting Cultivation Area in Central Kalimantan. *Journal of Forest Science*, 13: 181-194.

Morales-Hidalgo, D., Oswalt, S., & Somanathan, E. (2015). Status and trends in global primary forest, protected areas, and areas designated for conservation of biodiversity from the Global Forest Resources Assessment 2015☆. *Forest Ecology and Management*, 352, 68-77. https://doi.org/10.1016/j.foreco.2015.06.011.

Nakita C., Fatma U.N., 2022. The Impact of Deforestation and Efforts to Maintain Forest Sustainability in Indonesia. *Jurnal Ius Civile*, 6 (1): 92-103. [in Indonesia]

Nath, T. K., Dahalan, M. P. B., Parish, F., & Rengasamy, N. (2017). Local peoples' appreciation on and contribution to conservation of peatland swamp forests: Experience from Peninsular Malaysia. *Wetlands*, *37*(6), 1067-1077.

Numata, I., Elmore, A., Cochrane, M., Wang, C., Zhao, J., & Zhang, X. (2022). Deforestation, plantation-related land cover dynamics and oil palm age-structure change during 1990–2020 in Riau Province,

Indonesia. *Environmental Research Letters*, 17. https://doi.org/10.1088/1748-9326/ac8a61.

Obeng, A. S., Dunne, J., Giltrap, M., & Tian, F. (2023). Chemical signature of soil organic matter carbon, hydrophobicity, and humification index following land-use change in temperate peat soils. Heliyon, 9(9).

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419–422.

Perdana, L. R., Ratnasari, N. G., Ramadhan, M. L., Palamba, P., Nasruddin, & Nugroho, Y. S. (2018). Hydrophilic and hydrophobic characteristics of dry peat. In IOP Conference Series: Earth and Environmental Science (Vol. 105, No. 1, p. 012083). IOP Publishing.

Presidential Regulation of the Republic of Indonesia. (2022). *Presidential Regulation Number 111 of 2022 concerning the Implementation of the Achievement of the Sustainable Development Goals*. Available online. Accessed November 14, 2025.

Putri, V.S., Ibrahim., Febrian, L. (2021). Opportunities and Challenges in Managing the Bukit Mangkol Grand Forest Park Conservation Area. *Journal of Social and Science* 1 (6): 491-498 [In Indonesia]

Rampheri, M. B., & Dube, T. (2021). Local community involvement in nature conservation under the auspices of Community-Based Natural Resource Management: A state of the art review. *African Journal of Ecology*, *59*(4), 799-808.

Regional Development Planning Agency of Riau Province. (2022). *Sustainable Development of Riau 2019-2024*. Pekanbaru.

Ribeiro, K., Pacheco, F., Ferreira, J., De Sousa-Neto, E., Hastie, A., Filho, G., Alvalá, P., Forti, M., & Ometto, J. (2020). Tropical peatlands and their contribution to the global carbon cycle and climate change. *Global Change Biology*, 27, 489 - 505. https://doi.org/10.1111/gcb.15408.

Rossita, A., Nurrochmat, D. R., Boer, R., Hein, L., & Riqqi, A. (2021). Assessing the monetary value of ecosystem services provided by Gaung–Batang Tuaka peat hydrological unit (Khg), Riau Province. Heliyon, 7(10).

Santoso R., Ratnawati H., Riyanti D. (2022). Clustering of Deforestation Rates: Indonesia's Citizenship Ecology. *Indonesian Journal of Conservation,* 11(1): 34-38. [In Indonesia]

Shafitri L.D, Prasetyo, Y., Hani'ah. (2018). Analysis of Forest Deforestation in Riau Province Using the Polarimetric Method in Remote Sensing. *Journal of Geodesy*. 7 (1): 212-222. [In Indonesia]

Stupak, I., Mansoor, M., & Smith, C. T. (2021). Conceptual framework for increasing legitimacy and trust of sustainability governance. *Energy, sustainability and society*, *11*(1), 5.

Surahman, A., Soni, P., Shivakoti, G. P. (2017). Are Peatland Farming Systems Sustainable? Case Study on Assessing Existing Farming Systems in The Peatland of Central Kalimantan, Indonesia. *Journal of Integrative Environmental Sciences*, 15 (1): 1–19

Suwondo, S Wulandari, Darmadi, R Haryanto and I Ramdani. 2023. Dominance of palm oil plantation utilization on peatlands in Riau Province. *IOP Conf. Series: Earth and Environmental Science* 1230: 012001, doi:10.1088/1755-1315/1230/1/012001

Suwondo., Darmadi., Yunus, M. (2018). Ecosystem protection and management: an ecological political analysis of peatland utilization as industrial forest plantations. *Journal of Sustainable Environmental Management*, 2018, 2(2):140-154. [in Indonesia]

Syahza, A., Suwondo, Djaimi B., Besri, N., Riyadi, M., 2020. Utilization of Peatlands Based on Local Wisdom and Community Welfare in Riau Province, Indonesia. *International Journal of Sustainable Development and Planning*, 15 (7): 1119-1126.

Tan, L., Ge, Z., Zhou, X., Li, S., Li, X., & Tang, J. (2019). Conversion of coastal wetlands, riparian wetlands, and peatlands increases greenhouse gas emissions: A global meta-analysis. *Global Change Biology*, 26, 1638 - 1653. https://doi.org/10.1111/gcb.14933.

Word, C., Mclaughlin, D., Strahm, B., Stewart, R., Varner, J., Wurster, F., Amestoy, T., & Link, N. (2022). Peatland drainage alters soil structure and water retention properties: Implications for ecosystem function and management. *Hydrological Processes*, 36. https://doi.org/10.1002/hyp.14533.

Wu, Y., Zhang, N., Slater, G., Waddington, J., & De Lannoy, C. (2020). Hydrophobicity of peat soils: Characterization of organic compound changes associated with heat-induced water repellency. *The Science of the total environment*, 714, 136444. https://doi.org/10.1016/j.scitotenv.2019.136444.

Wunder, S. (2015). Revisiting the concept of payments for environmental services. *Ecological Economics*, 117, 234–243.

Wunder, S., Brouwer, R., Engel, S., Ezzine-de-Blas, D., Muradian, R., Pascual, U., & Pinto, R. (2021). Payments

for environmental services: Past performance and pending potentials. *Annual Review of Resource Economics*, 13, 209–234.