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RESEARCH ARTICLE

Analysis of Biodiversity Conservation in South Kalimantan, Indonesia: Investigating the Ecological Features of a Damaged Peat Ecosystem

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ABSTRACT

Protecting and preserving peat ecosystems and conducting a fundamental examination of ecological aspects are essential in peat ecosystems. This research aims to assess the ecological characteristics of peat ecosystems, focusing on vegetation and the growing environment. The study site is in the Haur Gading sub-district of South Kalimantan, Indonesia. Vegetation data were obtained using the nested sampling method, where 10 plots measuring 20 m x 20 m were established to record species count, individual count, and tree diameter within the peat forest cover. The validity and reliability of measured constructs were ensured through rigorous methods. Each plot also measured the abundance of the pole, sapling, and seedling vegetation. For each land cover type, soil and water measurements were conducted at three points. The collected data included water level, electrical conductivity, and pH of the peat soil and water. The vegetation data were analyzed using the Important Value Index and the Shannon-Wiener Index, while a tabulation matrix was used for analyzing soil, water, and specific vegetation components. Six vegetation types were identified in repeatedly burned peat forests, with a significantly lower species count than research findings in other areas. The presence of predominantly pure (relatively homogeneous) stands at the tree and pole levels indicates the extent of the damage. The resulting diversity index is also relatively low, suggesting ecosystem degradation. The pH levels of both soil and peat water are classified as acidic. Bringing empirical evidence from such a unique context is an advance in the literature in the field. The study provides several key policy and theoretical insights for scholars and practitioners in biodiversity.

INTRODUCTION

The peat ecosystem is renowned for its role as a crucial support system for life. Peatlands serve as direct providers of various life-sustaining resources, including freshwater fish, medicinal plants, food, and energy, while also serving as habitats for diverse organisms. Moreover, peat ecosystems possess essential regulatory functions such as flood control and global climate management (MEF 2017).

The expanse of peatlands across Indonesia's major islands, namely Sumatra, Kalimantan, and Papua, spans approximately 15 million hectares. Provinces with predominant peatlands include Riau, Central Kalimantan, West Kalimantan, and South Kalimantan, which encompass an area of 47,717 hectares of peat ecosystems (Department of the Environment, 2021).

Peatlands as ecosystems exhibit unique characteristics, such as low soil pH, subsidence, irreversibly dry conditions, and flammability when the hydrological system is disrupted. These peatlands have broadly been utilized for various purposes, including agriculture, illegal logging, plantation expansion, industrial plantation forest development, and other forms of land conversion (Herman, 2016).

Forest fires also pose a significant threat to peat ecosystems. In 2015, fires in South Kalimantan caused damage to peatlands, affecting an extensive area of 18,665 hectares. The peat ecosystem damage resulting from the 2015 fires impacted the Sungai Utar and Serapat River KHG (Peat Hydrological Unit). The Sungai Utar-Sungai Serapat KHG spans 44,956 hectares, with a peatland area of 15,905 hectares, accounting for 33% of the peat area in South Kalimantan (Department of the Environment, 2021).

Restoring damaged peatlands is a challenging task. Conservation becomes crucial given the significance of peat ecosystems for the environment and their limited ability to recover from disturbances. Effective conservation planning and implementation for peat rehabilitation rely on accurate data and information concerning the ecological characteristics of peatlands. Rehabilitation measures based on ecological data play a vital role in conserving degraded peat ecosystems and guiding protection and future management endeavors. This study aims to analyze both the biological characteristics (vegetation indicators) and physical characteristics (peat soil and water indicators) found in degraded peat ecosystems.

LITERATURE REVIEW

Peat ecosystems are globally recognized for their high biodiversity and ecosystem services, making their conservation imperative. Peatlands, including peat forests, play a crucial role in carbon storage, climate regulation, water regulation, and providing habitat for numerous plant and animal species (Hooijer et al., 2010; Singh et al., 2018). However, these ecosystems face substantial degradation and destruction due to human activities such as drainage for agriculture, logging, and land conversion.

South Kalimantan, Indonesia, is home to extensive peatland areas, and it has experienced significant peatland degradation in recent years (Miettinen and Liew, 2010). The conversion of peat forests into agricultural land, particularly for oil palm plantations, has resulted in the loss of biodiversity and increased greenhouse gas emissions (Miettinen et al., 2016). The Haur Gading sub-district in South Kalimantan has been subjected to substantial land-use changes, including peatland drainage and recurrent fires, leading to the degradation of peat ecosystems.

In a study by Page et al. (2004), the authors investigated the impacts of drainage and fire on peatland biodiversity in Southeast Asia. They found that drained peatlands experienced a loss of plant diversity, particularly in burned areas. The study emphasized the importance of conserving intact peat swamp forests and restoring degraded areas to preserve biodiversity and ecosystem functioning.

Studies on the ecological characteristics of peat ecosystems have utilized various methods to assess vegetation composition, soil properties, and hydrological conditions. Hamard et al. (2010) comprehensively analyzed peatland hydrological properties and their relationship with vegetation in Central Kalimantan, Indonesia. They employed hydrological modeling and vegetation surveys to evaluate the effects of water table depth on peatland vegetation distribution and composition.

Recent studies have also emphasized the role of peatland water management in conservation efforts. Wösten et al. (2008) examined the relationship between water table management and biodiversity in tropical peat swamps. They found that maintaining an optimal water table depth was crucial for preserving biodiversity and ecosystem functioning in peat swamp forests. One significant threat to peat ecosystems is the occurrence of fires, both natural and anthropogenic. Miettinen et al. (2016) studied burned peatland areas in Indonesia, including South Kalimantan, and found that fires significantly alter vegetation composition and reduce species diversity. The study highlighted the importance of understanding the ecological consequences of peatland fires for effective conservation planning.

Furthermore, studies have explored the impact of land-use change on peat ecosystems in South Kalimantan. Wijedasa et al. (2017) investigated the conversion of peatlands for oil palm plantations and found that this land-use change leads to significant biodiversity loss and greenhouse gas emissions. The study emphasized the need for sustainable land-use practices and restoration efforts to mitigate the adverse impacts on peat ecosystems.

In terms of conservation strategies, initiatives such as the Heart of Borneo (HoB) program have been established to protect the biodiversity-rich areas of Borneo, including South Kalimantan.

In summary, previous studies have highlighted the degradation of peat ecosystems. These studies have underscored the importance of assessing vegetation composition, soil properties, and hydrological conditions to evaluate ecosystem health and guide conservation efforts. However, there needs to be more research explicitly focusing on the ecological characteristics of damaged peat ecosystems in South Kalimantan's Haur Gading sub-district. This study aims to fill that knowledge gap by investigating the vegetation and growing environment of the damaged peat ecosystem in this area and providing essential evidence for conservation actions.

METHOD

Research objects and equipment

The study focuses on a peatland ecosystem encompassing various types of land cover, including forest, pure plant (*Lepironia Articulata*) areas, and open land. Geographically, the research site is situated in the Haur Gading District, within the North Hulu Sungai Regency of South Kalimantan. The research utilizes specific equipment, namely a comprehensive set of terrestrial survey tools such as a phi band, GPS meter, EC meter, pH meter, tally sheet, stationery, and camera for documentation purposes.

Data collection

Data regarding the ecological attributes of peatlands are expressed through various biological and chemical-physical parameters. The biological parameters were assessed by conducting vegetation measurements. To obtain vegetation data, a nested plot sampling approach was employed. Precisely, ten 20-m x 20-m plots were systematically positioned, taking into account the distribution of forest cover. Within each 20 m x 20 m plot, nested subplots were established to measure vegetation at different levels, including trees, poles, saplings, and seedlings. The plot size for tree data collection was 20 m by 20 m. A plot size of 10 m x 10 m was used for pole-level observations, while sampling-level measurements were conducted in 5 m x 5 m plots. Seedling-level data was gathered from 1 m x 1 m plots. Additionally, non-forest vegetation data were collected using 1 m x 1 m plots. The collected vegetation data encompassed the count of individual plants, species diversity, and diameter measurements for trees and poles. Furthermore, assessments were conducted to observe the dominant landscape and vegetation, providing additional insights into the ecological characteristics of the degraded peat forest. Figure 1 presents an overview of the field measurement plots.

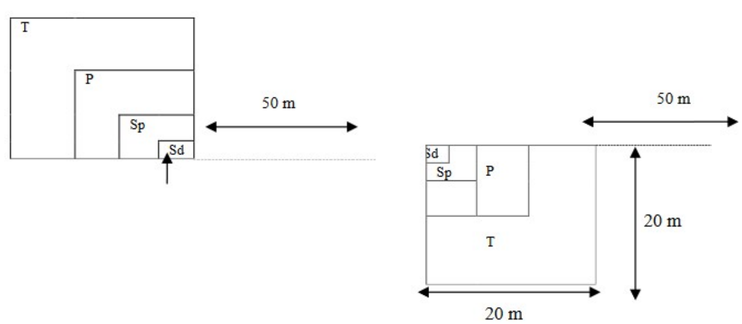

Figure 1: Description of vegetation data collection (Remarks: T= trees; P = pole; Sp= saplings, Sd= seedlings)

Measurements were conducted to gather data on the physical and chemical characteristics of the peatlands by assessing the properties of both soil and water. Considering the disturbed soil conditions, a comprehensive approach was employed to collect peat soil data for analysis. At least three sampling points were selected for each vegetation cover to collect soil and water samples. The pH, TDS (total dissolved solids), and EC (electrical conductivity) levels were measured using appropriate groundwater or canal water instruments. In addition, groundwater measurements could be conducted in boreholes made for soil or peat extraction.

Data analysis

The vegetation data analysis involved utilizing a tabulation matrix that considered both the species count and the Important Value Index (Soerianegara and Indrawan, 1998). The Shanon-Wiener Diversity Index (Ludwig and Reynolds, 1989) was employed to ascertain the diversity index of the vegetation. The formula utilized for calculating the Shanon-Wiener diversity index is as follows:

$$\mathrm{H}' = \sum Ln\frac{ni}{\mathrm{N}}x\frac{ni}{\mathrm{N}}$$

Remax: H' represents the Shannon-Wiener Index. Ln denotes the natural logarithm, ni signifies the number of individuals of type I, and N indicates the total number of individuals across all species.

Examining peat water's physical and chemical properties involved on-site direct detection through a pH meter, an EC meter, and a height meter. A tabulation matrix was employed to analyze the physical and chemical analyses. The assessment involved comparing biophysical attributes to those of peat ecosystems in previous studies as points of reference.

RESULTS AND DISCUSSION

Table 1 displays the findings of the vegetation analysis conducted on the secondary peat forest in the Haur Gading sub-district, North Hulu Sungai Regency. The damage to this peat ecosystem primarily stems from recurrent fires, while sporadic instances of unauthorized logging activities are infrequently observed.

Table 1: Species composition, Important Value Index, and Diversity Index of secondary forest

Nu	Species Composition	RDo (%)	RD (%)	RF (%)	IVI (%)	H'	Vegetation Level
1	*Adina minutiflora*	0	50	50	100	0.35	Seedling
2	*Combretocarpus rotundatus*	0	50	50	100	0.35	
	SUM		100	100	200	0.7	
1	*Adina minutiflora*	0	52	33,33	85.33	0.34	Sapling
2	*Syzygium sp.*	0	16	16,67	32,67	0.29	
3	*Melicope sp.*	0	4	8.33	12.33	0.13	
4	*Combretocapus rotundatus*	0	16	25	41	0.29	
5	*Pternandra azurea*	0	12	16,67	28,67	0.25	
	SUM		100	100	200	1.31	
1	*Combretocarpus rotundatus*	89.48	90,91	83,33	263.72	0.09	Pole
2	*Alstonia pneumatophora*	10.52	9.09	16,67	36,28	0.22	
	SUM	100	100	100	300	0.3	
1	*Combretocarpus rotundatus*	97,49	97,96	95,24	290.69	0.02	Tree
2	*Alstonia spp.*	2.51	2.04	4.76	9,31	0.08	
	SUM	100	100	100	300	0.1	

The repeated burning of secondary peat forests leads to a limited variety of tree species and hinders regeneration. These burned peat secondary forests predominantly consist of a few tree species, with *C. rotundatus*, exhibiting a dominance index value exceeding 250%. A relative density (RD) value above 90% indicates pure stands formed from forest fires. The biodiversity index value of the secondary forest formed after the fire has significantly decreased. The Shannon diversity index values (H') range from 0.10 to 1.31, placing them in the low category. The structural composition of the stands at different growth stages also indicates poor regeneration. *C. rotundatus* dominates at both the pole and tree levels, and this species can be found across all stages, including seedlings, saplings, poles, and trees. The sapling level contributes the highest number of species (5), while the other vegetation levels consist of only 2 species. Table 2 compares the species composition between repeatedly burned and non-burning peat forests.

Table 2: Comparison of species composition in the study location with other peat forests

Nu	Location/ Types of peat forest	Number of Vegetation Species	Information
1	Young secondary Peat Forest in Palangkaraya, Central Kalimantan	19	Yenihayati 2018
2	Young secondary peat forest in Bukit Batu Riau Province, Sumatra	45	Heriyanto et al. 2020
3	Old growth Peat Forest in Sebangau National Park, Central Kalimantan	99	Kalima & Denny 2019
4	Old growth Peat Forest in National Park Sentarum West Kalimantan	107	Randi et al. 2014
5	Repeat burned Peat Forest in Hulu Sungai Utara Regency South Kalimantan	6	Found in this research

The findings presented in Table 2 demonstrate that repeated fires in the peat ecosystem harm the biodiversity of existing vegetation. The loss of vegetation due to conservation reviews results in the depletion of wildlife habitats. According to information from the local community, the peat forest in the study area was previously a habitat for orangutans (Pongo pigment) to roam. However, since the occurrence of repeated fires, there has been a significant reduction in the movement of P. pigment within the peat forest. Additionally, Macaca fascicularis, a primate known for its wide range of habitat utilization, is rarely found in peat forests subjected to repeated burning. The limited availability of food sources resulting from the vegetation in these burned peat forests has led to the absence of various wild animals. Consequently, peat forests that have undergone repeated burning are no longer suitable habitats for wildlife. To restore the functionality of peat ecosystems, conservation efforts must be implemented to protect and rehabilitate the damaged areas.

Undergrowth vegetation observed in peat forests that have experienced repeated burning includes Nepenthes mirabilis, Stenochlaena phalustris, and Lepyronia articulata. Stenochlaena palustris predominantly grows in secondary forests and propagates on C. rotundatus tree trunks. The presence of S. palustris, a prominent characteristic of open peat forests, significantly covers the soil surface. This dominance is believed to hinder the introduction of other species into burned peat forests.

In burnt and unburned run deserts, the vegetation is mainly dominated by Lepyronia articulata, with occasional occurrences of C. rotundatus and A. minutia. The cultivation of L. articulata by the local community initially contributed to its presence, and it subsequently thrived naturally in the peat ecosystem area. This particular type of plant serves as a source of income for those who utilize it for weaving purposes.

Open areas are typically characterized by the prevalence of several aquatic weeds, such as Pistia stratiotes, Eichhornia crassipes, Ludwigia octovalvis, Scleria laevis, Phragmites karka, Salvinia molesta, and Lepyronia articulata. The high water level in these open lands is evident from the average inundation of +61.7 cm. Such inundation limits the growth of various vegetation types, particularly water plants that can thrive in open areas.

Additionally, the peat soil and water exhibit specific physical and chemical properties, some of which are outlined in Table 3.

Table 3: Characteristics of soil and water in Peat Ecosystems.

Land Covered	Water pH	Water EC	pH of peat	EC of peat	Water Level (cm)
Burned peat secondary forest	3,6	57,3	3,5	82.4	(-)10, (+) 22.7
Unburned *Lepironia articulata* land	3,4	59	3,5	95.9	(+) 29.3
Burned *Lepironia articulata* land	3,5	58	3,4	110.3	(+) 29.3
Open areas with shrubs	4,5	44.8	4,8	82.3	(+) 61.7

The acidity level of soil varies across different land areas, such as those with suitable soil pH and peat water, burned secondary peat forests, unburned *Lepironia articulata* land, burned *Lepironia articulata* land, and open areas with shrubs. The acid soil category includes the latter mentioned areas, while non-purun open land tends to have a higher pH value. This can be attributed to its proximity to the community's rice fields, where the land is often subjected to calcification. Additionally, the ash from previous rice field burnings reduces the area's overall acidity.

Pyrite content is exclusively found in open land areas covered with shrubs. The presence of pyrite is associated with the proximity of the river flow to these areas. Sediment carried by the river from upstream, which contains pyrite, is deposited around the adjacent regions to the river flow.

Referring to the data presented in Table 3, the peatlands exhibit a state of inundation indicated by a positive sign (+). However, in burned forest locations, certain spots may not be inundated. Forest land experiences the least inundation among the different land covers, while open areas with shrubs encounter the highest level. It is crucial to conduct conservation assessments to preserve forests, as they significantly reduce water levels. Forests help protect the peat component in the soil, known for its effective water absorption capabilities. The electrical conductivity of peat soils ranges from 82.3–110.3 S/cm, while water shows a range of 44.8–49 S/cm. The threshold for sensitivity to electrical conductivity in certain plants is 2250 S/cm. High electrical conductivity can impede plant water and nutrient uptake, leading to increased osmotic pressure. Specifically, high electrical conductivity can cause plant poisoning, primarily due to Na+ and Cl-ions. The swamp forest's location, relatively distant from the sea, results in low levels of Na+ and Cl-ions.

Given the swamp forest's ability to absorb water, reforestation programs (revegetation) are essential in conservation efforts. The low level of inundation observed in peat forests compared to other land covers indicates the effectiveness of vegetation in these areas in absorbing water. Therefore, selecting appropriate vegetation types from forest areas can be considered for revegetation activities in peat ecosystems.

Revegetation activities need to take specific characteristics of peat ecosystems into account. Degraded peat swamp lands exhibit reduced support for plant growth, primarily due to flooding and low pH. Rieley and Page (2008) explain that prolonged inundation during the rainy season hampers the early stages of tree growth as seedlings cannot tolerate excessive moisture. The success rate of planting efforts in peatlands could be much higher, mainly due to constraints like waterlogging and limited species adaptability. Only certain species, such as *S. balangeran*, can survive in degraded peatlands (Kissinger et al., 2022). Studies indicate that the survival rate of revegetation plants in degraded peat forests, even after 1-2 years, remains relatively low, at less than 50% (Lazuardi, 2004; Kissinger et al., 2022). These findings emphasize the significance of conservation actions in peat ecosystems. Forest fragmentation resulting from fires further impedes the natural recovery process of peat ecosystems. The slower pace of artificial recovery compared to the level of damage incurred should warn various stakeholders to prioritize conservation actions in peat ecosystems. Damage to peat ecosystems diminishes biodiversity and leads to a decline in other environmental qualities. Conservation actions encompass measures such as protection, rehabilitation, restoration, and socio-economic improvement for the local community involved in conservation efforts at the site level.

The theoretical implications of the study

The present study on the ecological features of a damaged peat ecosystem in South Kalimantan, Indonesia, has several theoretical implications for the fields of biodiversity conservation and peatland ecology:

Understanding the impacts of degradation: The study contributes to understanding the ecological consequences of peatland degradation. By examining the vegetation composition and growing environment of a damaged peat ecosystem, the study sheds light on the extent of damage and loss of biodiversity in such ecosystems. This knowledge is crucial for developing effective conservation strategies and restoration efforts.

Assessing the importance of vegetation diversity : The investigation of vegetation characteristics, such as species count, abundance, and diversity indices, provides valuable insights into the impacts of degradation on the peatland's ecological health. The study's findings can contribute to the theoretical understanding of the relationship between vegetation diversity and ecosystem functioning in peat ecosystems, emphasizing the significance of maintaining diverse plant communities for overall ecosystem resilience.

Examining the role of disturbances: The study highlights the ecological consequences of recurrent fire events by focusing on repeatedly burned peat forests. This analysis contributes to the theoretical understanding of the long-term impacts of fires on peatland ecosystems, including changes in vegetation structure, reduced species richness, and alterations in ecosystem processes. The study adds to the existing knowledge of the complex dynamics between disturbances, biodiversity, and ecosystem functioning in peatland environments.

Highlighting the importance of hydrological conditions: The investigation of soil and water properties, such as pH levels and water storage capacity, provides insights into the hydrological conditions of the damaged peat ecosystem. The study's findings can contribute to theoretical frameworks on the role of hydrology in shaping peatland ecology, emphasizing the significance of maintaining appropriate water levels and preventing drainage for ecosystem conservation.

Enhancing conservation strategies: The research underscores the urgent need for conservation actions in peat ecosystems, specifically in South Kalimantan. The theoretical implication lies in implementing integrated conservation approaches that address land-use change, fires, and restoration efforts. The study's findings can inform theoretical frameworks on landscape-scale conservation planning, emphasizing the role of collaboration among stakeholders and the incorporation of local communities in conservation initiatives.

Overall, this study on the ecological features of a damaged peat ecosystem in South Kalimantan contributes to the theoretical understanding of peatland ecology, biodiversity conservation, and the implications of degradation and disturbance events. The findings provide valuable insights for theoretical research and practical conservation strategies to preserve and restore peatland ecosystems.

Practical Implications of the study

The study on the ecological features of a damaged peat ecosystem in South Kalimantan, Indonesia, has several practical implications for biodiversity conservation and peatland management.

Conservation prioritization: The findings of the study can aid in prioritizing conservation efforts in South Kalimantan by highlighting the areas most in need of protection and restoration. Identifying severely damaged peat forests and the associated loss of biodiversity can guide conservation organizations and policymakers in allocating resources and implementing targeted conservation measures in these vulnerable areas.

Restoration planning: The study provides crucial information for planning and implementing restoration initiatives in damaged peat ecosystems. By identifying the specific vegetation composition and the extent of damage, restoration practitioners can develop appropriate strategies to promote the recovery of the peatland ecosystem. This may include reestablishing key vegetation species, controlling fire incidents, and implementing hydrological restoration techniques to restore water levels.

Fire management strategies: The study's findings regarding the impacts of fires on peatland ecosystems can inform fire management strategies and policies. Understanding the ecological consequences of recurrent fire events can support the development of fire prevention and mitigation measures, such as implementing firebreaks, promoting community-based fire monitoring, and raising awareness about the risks and impacts of peatland fires.

Sustainable land-use practices: The study emphasizes the negative impacts of land-use change, particularly the conversion of peatlands for agriculture, on peat ecosystems in South Kalimantan. This highlights the need for sustainable land-use practices, such as agroforestry or low-impact agricultural techniques, that minimize the adverse effects on peatland biodiversity and ecosystem services. The findings can inform land-use planning and policy development to ensure the long-term sustainability of peatland landscapes.

Stakeholder engagement and awareness: The study's findings can raise awareness among local communities, stakeholders, and policymakers about the importance of peatland conservation. By communicating the ecological features of damaged peat ecosystems and their significance for biodiversity, water storage, and climate regulation, the study can foster greater stakeholder engagement and support for conservation efforts. This can lead to improved collaboration among various stakeholders and development of participatory approaches to peatland management.

Overall, the practical implications of this study lie in its potential to guide conservation prioritization, restoration planning, fire management strategies, land-use practices, and stakeholder engagement. By applying the findings and recommendations of the study, policymakers, conservation practitioners, and local communities can work together to protect and restore damaged peat ecosystems in South Kalimantan, safeguarding biodiversity, maintaining ecosystem services, and promoting sustainable land-use practices.

Limitations of this study

While the study on the ecological features of a damaged peat ecosystem in South Kalimantan provides valuable insights, it is essential to acknowledge its limitations:

Limited spatial scope: The study focuses on a specific area in the Haur Gading sub-district of South Kalimantan, which may only represent part of the range of peatland ecosystems in the region. The study findings might need to be more generalizable to other peatland areas in South Kalimantan or other regions with different ecological characteristics.

Lack of temporal data: The study provides a snapshot of the damaged peat ecosystem's ecological features at a specific time. Long-term monitoring data would provide a more comprehensive understanding of the ecosystem dynamics, including changes in vegetation composition, hydrological conditions, and the recovery process following disturbances. With long-term data, it is easier to assess ecosystem degradation and recovery trajectory.

Potential for sampling bias: The study utilized the nested sampling method, establishing 10 plots within the peat forest cover. The selection of these plots and their spatial distribution may introduce potential sampling bias, which could affect the representativeness of the data. The study could benefit from a larger sample size or a randomized sampling design to enhance the robustness of the findings.

Limited focus on faunal biodiversity: While the study provides insights into vegetation characteristics and water properties, it does not extensively examine the faunal biodiversity of the damaged peat ecosystem. Considering the importance of biodiversity conservation in peatlands, a more comprehensive assessment that includes fauna would provide a more holistic understanding of the ecosystem's ecological features.

Potential for data gaps: The study collected data on vegetation, soil properties, and peat water properties, but other critical ecological variables, such as nutrient levels, carbon storage, and microbial communities, were not included in the analysis. These additional data could contribute to a more comprehensive assessment of the ecosystem's ecological features and processes.

Limited socioeconomic analysis: The study primarily focuses on the ecological aspects of the damaged peat ecosystem, and socioeconomic factors, such as local livelihoods, land-use policies, and community engagement, need to be extensively addressed. Considering the importance of integrating social and economic dimensions into conservation strategies, a more comprehensive analysis of these aspects would provide a broader understanding of the challenges and opportunities for peatland conservation.

Acknowledging these limitations is important for accurately interpreting the study's findings and identifying areas for future research and data collection to enhance our understanding of damaged peat ecosystems and improve conservation efforts.

Future research directions

Studying the ecological features of a damaged peat ecosystem in South Kalimantan opens up several avenues for future research to further advance our understanding of peatland conservation and ecosystem restoration. Some potential research directions include:

Long-term monitoring: Conducting long-term monitoring studies in the same or similar peatland areas would provide valuable insights into the trajectory of ecosystem degradation and recovery over time. By collecting data at regular intervals, researchers can assess the long-term impacts of disturbances, such as fires and land-use change, on vegetation composition, hydrological conditions, and biodiversity dynamics.

Comparative studies: Undertaking comparative studies across different peatland areas in South Kalimantan or other regions would help identify variations in ecological features, vegetation composition, and ecosystem processes. Comparing undisturbed peat ecosystems with damaged or restored ones would provide insights into the effectiveness of conservation and restoration measures, highlighting the factors contributing to successful ecosystem recovery.

Faunal biodiversity assessment: Extending the research to include comprehensive assessments of faunal biodiversity in damaged peat ecosystems would enhance our understanding of the ecological dynamics and interactions within these ecosystems. Investigating the responses of different faunal groups, such as mammals, birds, reptiles, and invertebrates, to disturbances and restoration efforts would provide valuable information for biodiversity conservation strategies.

Landscape-scale conservation planning: Examining peatland ecosystems' broader landscape context and connectivity would contribute to developing effective conservation planning strategies. Research could focus on understanding the connectivity of peatland patches, the role of buffer zones, and the influence of surrounding land uses on peat ecosystems' ecological health and resilience.

Socioeconomic assessments: Integrating socioeconomic analyses into research is crucial for understanding the human dimensions of peatland conservation and restoration. Future studies could investigate the socioeconomic factors driving land-use change, the impacts of conservation policies on local communities, and the effectiveness of community-based conservation and sustainable livelihood initiatives in promoting peatland conservation.

Hydrological modeling and management: Conducting hydrological modeling studies to simulate different hydrological restoration scenarios would provide insights into the potential outcomes of various management interventions. Investigating the hydrological connectivity between peatland areas, the effects of water table management on vegetation recovery, and the interactions between hydrology and carbon dynamics would advance our understanding of peatland ecosystem functioning.

Climate change impacts: Assessing the vulnerability of damaged peat ecosystems to climate change and exploring their potential feedback on the climate system would be valuable. Future research could investigate the impacts of rising temperatures, altered precipitation patterns, and sea-level rise on peatlands' ecological features and resilience, helping to guide adaptation strategies in the face of climate change.

By pursuing these research directions, we can deepen our understanding of peatland ecology, refine conservation and restoration approaches, and contribute to the sustainable management of peat ecosystems in South Kalimantan and beyond.

CONCLUSION

The biodiversity of vegetation in degraded peat ecosystems is significantly diminished due to repeated fires. Peat forests that have experienced multiple burn incidents now exhibit only six distinct vegetation types. These recurrent fires have transformed the initially diverse peat forest into a uniform and homogeneous forest, with C. rotundatus dominating the landscape. The decline in vegetation diversity adversely affects the suitability of the peat ecosystem as a habitat for wildlife, hampering their lives and development. Furthermore, the degradation of peat ecosystems hampers their ability to effectively store water. The damage inflicted on the peat ecosystem has also led to various reductions in environmental quality. It is imperative to undertake conservation efforts to mitigate the damage, protect the ecosystem, and implement rehabilitation measures to restore its functionality.

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