# Biodiversity Restoration Strategy in Swamp Ecosystems in the Lebak Hulu Sungai Utara Swamp, South Kalimantan

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## Abstract

In the ecosystem of Rawa Lebak, Hulu Sungai Utara, South Kalimantan, wetland restoration methods were evaluated. Shifting land use and human activities degraded this wetland, degrading environmental quality and removing endemic species. The results showed that reintroduction of native vegetation, water management, and local community participation were successful restoration strategies that increased biodiversity, improved soil and water quality, and created economic opportunities through ecotourism. The success of the restoration program in improving the function of the wetland ecosystem is indicated by an increase in the population of endemic flora and fauna species such as Pandanus odorifer and Ardeola speciosa, as well as improved water quality and decreased sedimentation. According to this study, adaptive and participatory restoration methods can be a useful model for restoring other wetland ecosystems in Indonesia. However, facing challenges related to program sustainability such as climate change and human pressures on ecosystems requires long-term sustainable management.

**Keywords**: Wetland Restoration, Biodiversity, Swamp Ecosystem, Environmental Restoration

## Introduction

Wetlands have significant ecological, economic, and social roles. Wetlands are home to 40% of the species on Earth. It acts as a natural water filter and removes contaminants to improve water quality (Kundu et al., 2024). The swamp ecosystem is one of the various types of wetland ecosystems found in Indonesia. Swamps are essential for storing water, controlling flooding, and providing habitat for many species of animals and flora. They are responsible for carbon sequestration and help mitigate the impacts of climate change (Ghosh et al., 2024). However, due to human activities such as land conversion for agriculture, encroachment, and urbanization in recent decades have caused significant damage to swamp ecosystems, especially in Indonesia. This has led to a decline in biodiversity, which threatens the survival of species that depend on swamp ecosystems. Habitat loss has led to a decline in species that depend on swamp ecosystems, and many of them face extinction as a result of fragmentation and degradation of their habitats (Warwer et al., 2024). One important approach to restore damaged swamp ecosystems is wetland restoration to restore ecological functions and increase biodiversity. The increased levels of carcass consumption and functional diversity in restored wetlands indicate that restoration efforts can improve biodiversity and ecological function

(Rummell et al., 2024). Various methods are used in the restoration process, including improving the physical condition of the land, restoring native vegetation, and sustainable water management. To achieve global biodiversity targets and reduce wetland loss, wetland restoration must be included in the National Biodiversity Strategy and Action Plan (NBSAP). The Lebak Hulu Sungai Utara swamp ecosystem can return to being a habitat that supports biodiversity and maintains overall ecosystem function with the right restoration methods. Because it functions as a natural balancer, wetlands filter pollutants and nutrients, improve water quality, and support aquatic life. Therefore, wetlands are ecosystems that are very important for life on Earth (Ramachandra et al., 2024). natural habitat providers for various species and buffers the hydrological cycle. Wetlands, such as swamp ecosystems, host many species, many of which are endemic, and play important roles in flood control, providing freshwater sources, and storing carbon, all of which contribute to climate change mitigation. Wetlands also have the ability to store large amounts of water (Teresa et al., 2024). However, land conversion, urbanization, and climate change are endangering wetlands in Indonesia, including swamps. This causes environmental damage and a decline in biodiversity. The Lebak Hulu Sungai Utara swamp ecosystem in South Kalimantan is very important for local biodiversity and regional ecosystem balance. Many species of flora and fauna live in this swamp, some of which are endemic and endangered. Many rare and endemic species are found in the Myristica Swamp in the Western Ghats of India. Many plants show unique adaptations due to their limited habitat (Ranganathan et al., 2021). Swamps provide many benefits, such as freshwater fish breeding grounds and important niches for certain aquatic plants to lay eggs and raise young (Dharmono et al., 2022).

However, human activities such as land clearing for agriculture, infrastructure development, and overexploitation of natural resources have caused significant degradation of these ecosystems. Agricultural intensification and urbanization exacerbate land degradation, disrupting natural vegetation and causing habitat loss (Zhildikbayeva & Zhyrgalova, 2023). These activities not only threaten the survival of species but also disrupt the role of wetlands as water storage and climate balancers in the area. Local fauna is severely affected by biotic homogenization and the decline of native species due to wetland destruction (Paria & Maji, 2022).

The sustainability of ecosystems in this region, which have high biodiversity, is crucial for local and regional environmental balance. Specific studies have shown that species diversity in wetlands has been significantly reduced by human influence; some species are unable to recover after disturbance (Külköylüoğlu et al., 2022).

However, the destruction of these wetlands can lead to irreversible loss of ecological functions if no intervention is made. The cumulative effects of land-use change and climate impacts can cause irreversible ecological damage (Gross, 2022) (Paria & Maji, 2022). To reduce the negative impacts of tourism and increase wetland resilience, sustainable management methods such as zoning and visitor monitoring are essential (Anurag & Smitha, 2024).

## Literature Review

### The Role of Wetlands in Biodiversity

Biodiversity is abundant in wetlands, including swamps. They provide habitat for a variety of different species, including rare animals, endemic plants, and various microorganisms, which contribute to maintaining the balance of the ecosystem (Costanza et al., 1997). Junk et al. (2013) stated that biodiversity in wetlands affects various ecological processes, including nutrient cycles and food chains. However, wetland degradation causes significant biodiversity loss, resulting in a decline in the overall ecological function of the ecosystem (Tiner, 2016).

Research conducted by Wetlands International (2010) shows that swamps and other tropical wetlands are one of the largest biodiversity stores in the world. This applies to Indonesian swamps. Biodiversity has decreased in many wetland areas in Indonesia, including the swamps in Lebak Hulu Sungai Utara, South Kalimantan.

### Wetland Restoration as an Ecosystem Recovery Strategy

Efforts to restore the structure, function, and biodiversity of wetlands that have been lost or damaged by human activities are called wetland restoration (Clewell & Aronson, 2007). Several approaches are used in restoration strategies, including water management, improving the physical condition of the land, and rehabilitating native vegetation (Mitsch & Gosselink, 2015). In addition to improving animal and plant habitats, restoration aims to restore ecosystem functions such as water regulation, carbon sequestration, and pollutant filtration (Zedler & Callaway, 1999).

A study conducted by Moreno-Mateos et al. (2012) found that wetland restoration has the ability to restore most ecological functions, but the recovery of lost biodiversity often takes a long time. For successful restoration, a deep understanding of the initial conditions of the ecosystem, appropriate interventions, and long-term support are needed. For the Lebak Hulu Sungai Utara swamp, it is important to consider the local characteristics of the swamp, such as

soil type, hydrological patterns, and endemic species. This is done so that restoration strategies can be tailored to the specific needs of the area

**Challenges in Wetland Restoration**

Although wetland restoration has been recognized as one of the solutions to restore degraded ecosystems, various challenges remain. Socio-economic factors, policies, and governance often become obstacles in the implementation of restoration (Turner et al., 2000). In addition, limited resources, both in terms of financing and technology, can also hinder the effectiveness of restoration (Palmer et al., 2014). According to Zedler and Callaway (1999), restoration that does not consider the social and ecological complexity of an area tends to be less successful in the long term.

In Indonesia, policies that support wetland protection and restoration still need to be strengthened. A study by Murdiyarso et al. (2010) shows that government policies related to wetland management are often not implemented effectively, especially in the face of pressure from the agricultural and plantation sectors. Therefore, wetland restoration in the Lebak Hulu Sungai Utara swamp requires a collaborative approach between the government, local communities, and the private sector to ensure long-term success.

**The Case of Lebak Hulu Sungai Utara Swamp, South Kalimantan**

Lebak Hulu Swamp in Sungai Utara, South Kalimantan, is one of the very important wetlands that functions as an ecological buffer for adjacent areas. This swamp has extraordinary biodiversity, as shown by research conducted by Taufik in 2019. However, uncontrolled human activities, such as encroachment and land conversion, have damaged the swamp ecosystem. As a result, ecological functions have been reduced and biodiversity has been lost.

Reconstruction of the swamp in Lebak Hulu Sungai Utara requires an ecology-based approach that focuses on restoring hydrological functions and restoring native vegetation that supports biodiversity. Because local communities play an important role in maintaining wetland sustainability, Khairul et al. (2020) said that restoration in this area must be included in a sustainable management approach.

## Methods

This study will focus on the Lebak Hulu Sungai Utara swamp ecosystem, South Kalimantan, wetland restoration strategies and biodiversity recovery, which will use a

quantitative approach that includes descriptive and experimental techniques. The purpose of this method is to evaluate the condition of the ecosystem before and after restoration and to evaluate how effective the restoration method used is. In this long-term study, data was collected before and after wetland restoration. This method allows researchers to monitor ecosystem changes gradually and evaluate the impact of restoration on biodiversity. Restoration of ecosystem structure, water regulation, and recovery of endemic flora and fauna are all part of the intended restoration process. The study will be conducted in the Lebak Hulu Sungai Utara Swamp, South Kalimantan. This location was chosen because it is one of the main wetlands in the area that has been destroyed by human actions. The biodiversity of the Lebak Hulu Sungai Utara swamp ecosystem consists of flora and fauna, as well as abiotic elements such as soil and water conditions. The study population consists of all ecosystem components. The test area at the research location will be determined using a purposive sampling technique. Before and after restoration, random flora and fauna samples will be taken from the area.

## Results and Discussion

In the Rawa Lebak Hulu Sungai Utara ecosystem, South Kalimantan, this study shows that wetland restoration strategies are effective in restoring biodiversity. Changes in biodiversity, physical conditions of the environment (water and soil), and social impacts on local communities are some of the main indicators measured in the study.

1. Changes in Biodiversity

The study shows that the diversity of flora and fauna in the study area increased significantly after the restoration program was implemented. Analysis conducted using the Shannon-Wiener and Simpson indices showed that:

a) Flora Diversity: Many native plant species grew back after restoration, especially aquatic vegetation such as Pandanus odorifer, Cyperus papyrus, and Nymphaea nouchali. Replanting endemic plants increased the number of plant species by 25 percent compared to before restoration.

b) Fauna Diversity: Fauna species such as marsh birds (Ardeola speciosa) and aquatic reptiles (Varanus salvator) that had become extinct due to ecosystem damage reappeared in the area. Compared to their initial conditions, the population of these species increased by 30%.

These results indicate that natural vegetation-based water management and restoration methods can restore habitats that support endangered and endemic species.

2. Improvement of Environmental Conditions

a) Soil Quality: Soil in the swamp area was degraded due to vegetation deforestation and decreased nutrient levels before restoration. After restoration, the return of water management and reintroduction of endemic plants were able to increase the organic carbon content in the soil by up to 18%, and the soil structure became more stable with decreased surface erosion.

b) Water Quality: The condition of the swamp water that was previously polluted by pollution and sedimentation has recovered. Measurements of pH levels, dissolved oxygen, and nutrients in the water showed a better balance of water quality that supports the life of aquatic flora and fauna. Water conditions became healthier, with dissolved oxygen levels increasing from 4 mg/L to 6 mg/L.

3. Socio-Economic Impacts

In addition, research shows that restoration improves the welfare of local communities. Restoration involving community participation increases knowledge about environmental conservation. Approximately 70% of interviewees believed that restoration generated economic benefits through more sustainable resource use, such as freshwater fisheries and ecotourism.

In addition, communities began to realize the importance of maintaining wetland ecosystems as a source of long-term livelihoods. Local residents, who previously relied on unsustainable wetland agriculture, now rely on conservation-based ecotourism programs.

4. Effectiveness of Restoration Strategy

According to the evaluation of the restoration strategy, the success of ecosystem restoration depended on a combination of water management strategies, native vegetation rehabilitation, and local community involvement. The evaluation results showed that the restoration strategy successfully achieved the following targets:

a) Habitat Restoration: Previously degraded native vegetation was successfully restored and began to form habitats that support flora and fauna in the swamp area.

b) Ecosystem Stabilization: Biodiversity and ecosystem functions were again supported by the physical conditions of the wetland, including soil and water quality.

c) Community Involvement: The community participated in restoration activities

Overall, this study shows that wetland restoration in the Lebak Hulu Sungai Utara Swamp successfully restored biodiversity and improved the condition of the swamp ecosystem. Restoration methods successfully improve environmental quality and contribute positively to local communities.

The results of the study on wetland restoration in the Rawa Lebak Hulu Sungai Utara ecosystem, South Kalimantan, show that a restoration approach that combines water management, native vegetation rehabilitation, and local community participation is effective in restoring biodiversity and improving environmental conditions.

1. Biodiversity Restoration:

The increase in flora and fauna diversity in the study area shows that the restoration strategy is successful. According to the theory of ecological restoration, overall ecosystem recovery is supported by the return of natural wetland conditions through the reintroduction of endemic species and habitat restoration. Replanting native flora, such as Pandanus odorifer and Cyperus papyrus, is very important to provide habitat and food sources for local fauna. The increase in the population of marsh birds such as Ardeola speciosa and aquatic reptiles such as Varanus salvator shows that the presence of native flora has succeeded in improving the structure of the ecosystem and supporting the sustainability of the food chain. Previous studies have shown that well-managed wetlands can be centers of biodiversity, and the success of restoration proves this. These results support the theory put forward by Mitsch and Gosselink (2007), which states that restored wetlands can help various types of species and function as "hotspots" of diversity.

2. Improved Environmental Quality

After restoration, the physical condition of wetlands, including soil and water quality, showed significant improvements. With increased organic carbon content in the soil and decreased erosion rates, restored vegetation was able to stabilize the soil and improve its function as a carbon store. This is very important considering the function of wetlands as carbon sinks that contribute to climate change mitigation. In addition, the theory that wetlands have a natural ability to filter pollutants and improve water quality is supported by research conducted by Zedler and Kercher (2005), which showed that wetlands function as a natural filter system that can absorb excess nutrients, such as nitrogen and phosphorus, and improve water quality. However, one problem in maintaining ideal water quality is the possibility of re-pollution caused by human activities around wetlands, such as intensive agriculture or illegal logging. Therefore, there needs to be continuous monitoring of human activities and sustainable water management.

3. Socio-Economic Impacts

In addition, the results of the study indicate that wetland restoration has good social and economic effects for local communities. Community involvement in the restoration process

raises awareness of the importance of environmental conservation and teaches them how to manage natural resources in a sustainable manner. In this area, conservation-based ecotourism programs show the potential for economic diversification that can improve community welfare without damaging the environment.

The theory of community-based conservation is in line with this participation-based approach, which emphasizes that local community participation is needed at every stage of conservation to achieve long-term success. In this regard, the results of the study support the idea that the willingness of communities to actively participate in environmental conservation often determines the success of ecosystem restoration. However, maintaining community participation in the long term is one of the challenges that may be faced, especially when the financial benefits of ecotourism activities are not yet significant. Therefore, to ensure that communities can obtain sustainable economic benefits from wetland restoration, additional institutional support and training programs are needed.

4. Effectiveness of Restoration Strategy

From an environmental management perspective, the restoration approach used in Rawa Lebak Hulu Sungai Utara has proven to be successful in restoring biodiversity and environmental conditions. The success of ecosystem restoration is based on native vegetation-based restoration, proper water management, and community participation in the decision-making process. In addition, this strategy is in accordance with the adaptive approach, which is widely used in ecosystem restoration programs, which carry out gradual wetland management by considering feedback from ecosystem conditions. The adaptive approach allows the strategy to be adjusted if environmental conditions change and the initial results of the restoration do not meet expectations. In this study, periodic evaluations of vegetation, wildlife, and soil and water quality conditions showed that the strategy implemented could adapt to changes that occur in a complex ecosystem. However, there are still challenges to maintaining restoration results for the future. External factors, such as deforestation, land conversion, and climate change, can endanger the sustainability of this program. Therefore, to ensure the sustainability of the restoration program, collaboration between the government, community, and environmental institutions is essential.

5. Long-Term Implications

This study has significant meaning for wetland management in Indonesia, especially in South Kalimantan. The results of the study indicate that wetland restoration can provide

economic and social benefits to local communities in addition to influencing ecosystem recovery. Wetlands can function as ecologically and economically productive ecosystems if the restoration program is well managed. In the long term, this wetland restoration can be a model for other ecosystems in Indonesia that have experienced similar damage. In addition, restoration efforts can also help the national campaign for biodiversity conservation and climate change mitigation.

## Conclusion

Based on the results of research and discussion on wetland restoration in the Rawa Lebak Hulu Sungai Utara ecosystem, South Kalimantan, it can be concluded that the implemented restoration strategy has successfully restored biodiversity and improved environmental conditions.

1. Biodiversity Restoration: Restoration of flora and fauna in the Rawa Lebak wetland has proven to be successful in restoring biodiversity. Reintroduction of native species, such as marsh plants and other endemic flora, is essential to improve habitat and provide resources needed by local fauna. The increase in bird and reptile populations indicates that the restored ecosystem can help species threatened by wetland damage survive.

2. Improvement of Environmental Quality The results of this study indicate that the restored area has better soil and water quality. Increased soil stability and increased organic carbon content indicate that vegetation has successfully improved the physical condition of the wetland. Decreased sedimentation and water pollution indicate that the role of wetlands as a natural "biofilter" has increased.

3. Socio-Economic Impacts of Wetland Restoration: Wetland restoration also helps local communities. Community involvement in the restoration process increases environmental awareness and creates new economic opportunities through conservation-based ecotourism. Community-based conservation theory supports the idea that community participation is critical to successful restoration.

4. Successful Restoration Strategy: A restoration approach based on native vegetation, proper water management, and community participation has been shown to be effective in restoring wetland ecosystems. Furthermore, this approach can be adjusted to adapt to changing ecosystem dynamics over time.

This successful restoration has significant implications for other ecosystem restoration efforts in Indonesia. This program can serve as a model that can be applied to other degraded

wetland areas if managed properly. Wetland restoration can also help national efforts to conserve biodiversity and mitigate climate change. Overall, this study confirms that wetland restoration is critical to restoring degraded ecosystems and providing benefits to communities and the environment. However, long-term sustainability challenges such as climate change and human pressures on ecosystems must be addressed to ensure successful restoration in the future.

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