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Innovative Strategies for Restoration of Degraded Ecosystems: A Case Study of Abandoned Agricultural Land and Abandoned Mining Land Recovery in West Java Province

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ABSTRACT

Ecosystem degradation and land abandonment are pressing global environmental challenges, with significant ecological, social, and economic consequences. In the context of West Java Province, Indonesia, the degradation of abandoned agricultural and mining lands has been a particularly pronounced issue. This study explored innovative strategies for the restoration of these degraded ecosystems, focusing on the recovery of abandoned agricultural and mining lands in West Java. The research employed a mixed-methods approach, combining quantitative and qualitative data collection methods. Key findings revealed a range of innovative strategies, including natural regeneration, agroforestry, phytoremediation, and soil improvement techniques, being used to restore abandoned lands. Challenges such as slow ecological recovery, community conflicts, and technical hurdles were also identified. Despite these challenges, the restoration efforts have yielded positive ecological, social, and economic outcomes, including increased biodiversity, improved soil quality, enhanced community livelihoods, and economic benefits. This study provides valuable insights into the complex process of ecosystem restoration in West Java Province and offers recommendations for policymakers, landowners, and conservation practitioners. The findings underscore the importance of community engagement, sustainable land management practices, and ongoing monitoring and research to support the long-term success of ecosystem restoration initiatives.

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1. INTRODUCTION

Ecosystem degradation and land abandonment in West Java Province, Indonesia, have led to severe ecological consequences, impacting biodiversity, ecosystem services, and human livelihoods. Abandoned agricultural lands and former

mining sites have suffered significant ecological degradation over the years. Land abandonment is a common issue in many parts of the world, driven by factors such as socio-economic changes, population decline, and policy failures [1], [2]. In the Mediterranean Basin, for example, the abandonment of traditional land-use practices has been reported as one of the main causes of decline for open-habitat species [3]. In European Russia, massive abandonment of arable land in the 1990s led to a decrease in provisioning ecosystem services, while creating opportunities to enhance the supply of diverse regulation services [4]. In the case of West Java Province, Indonesia, the degradation of ecosystems, particularly in abandoned agricultural lands and former mining sites, has far-reaching consequences. These consequences include the loss of biodiversity, decline in ecosystem services, and negative impacts on the well-being of local communities. To address these challenges, it is crucial to implement effective environmental management and landscape planning strategies that consider the complex socio-economic and ecological factors driving land abandonment and ecosystem degradation.

Some potential solutions include: Restoration and reforestation of degraded lands to improve ecosystem services and biodiversity [2]. Implementing sustainable land-use practices, such as agroforestry and conservation agriculture, to prevent further degradation and promote ecological resilience [5]. Encouraging community-based conservation and management initiatives to involve local stakeholders in the protection and restoration of ecosystems [6]. Developing and implementing policies that address the root causes of land abandonment, such as socio-economic factors, population decline, and policy failures [1]. By addressing the challenges of ecosystem degradation and land abandonment in West Java Province, Indonesia, it is possible to improve the ecological health of the region, enhance the well-being of local communities, and promote long-term sustainability.

Abandoned agricultural lands, once fertile and productive, are no longer in use due to a variety of factors, including economic shifts, changing land use patterns, and environmental degradation [7]–[9]. Similarly, abandoned mining lands have left scars on the landscape, with degraded soil quality, compromised water resources and loss of biodiversity. These issues require innovative and sustainable strategies to restore these degraded ecosystems, enhancing their ecological, social and economic value [10], [11].

The importance of ecosystem restoration cannot be overstated, given its potential to mitigate the adverse impacts of climate change, conserve biodiversity, and enhance ecosystem services such as clean water provision and carbon sequestration. In the context of West Java Province, where agricultural and mining activities have played a significant role in the region's history and economy, restoration of degraded land takes on a unique significance. This research is driven by the need to understand the innovative strategies used to restore abandoned lands in West Java, assess the challenges faced in the restoration process, and examine the outcomes achieved. By investigating these aspects, this research seeks to contribute to the growing body of knowledge on ecosystem restoration, offer insights into sustainable land management practices, and provide recommendations for policy makers, landowners and conservation practitioners.

2. LITERATURE REVIEW

2.1 Ecosystem Restoration: Concepts and Significance

Ecosystem restoration is a process that aims to assist the recovery of ecosystems that have been degraded, damaged, or destroyed, with a focus on restoring biodiversity, ecosystem services, and ecological resilience [12]. There are several ways to approach ecosystem restoration, and one such approach is to target habitat diversity. Habitat diversity, the spatial heterogeneity between and within habitat

patches in a landscape, is a well-known driver of species diversity and can help increase species diversity at multiple trophic levels [12]. To facilitate the uptake of habitat diversity in terrestrial ecosystem restoration, it is important to distinguish between compositional and structural habitat diversity, as different animal groups will respond to different aspects of habitat diversity [12]. Four methods have been proposed to increase habitat diversity in restoration projects: varying the starting conditions to obtain divergent successional pathways, emulating natural disturbances, establishing keystone structures, and applying ecosystem engineer species [12]. Restoration projects can have various ecological, social, and economic benefits. They can help revive populations of native species, protect biodiversity, sequester carbon to mitigate climate change impacts, enhance ecosystem services such as clean water provision, flood regulation, and pollination, and provide employment opportunities and enhance the well-being of local communities [12]. However, it is essential to have robust and consistent data on the costs and benefits of restoration to ensure the success of these projects [13]. A standard framework for assessing the costs and benefits of restoration projects can help improve the robustness and comparability of data on the economics of ecosystem restoration collected from the field at a global scale [13].

2.2 Degraded Ecosystems in West Java Province

Abandoned agricultural lands in West Java have experienced a decline in productivity due to factors such as urbanization, land use changes, and soil degradation [14], [15]. This degradation has raised concerns about food security, rural livelihoods, and the loss of agricultural diversity. In Sukabumi City, for example, a Sustainable Food Agricultural Land Protection Policy was implemented to protect 321 hectares of agricultural land, but as of early 2021, only about 10.024% of the planned land was ready for protection [14]. Additionally, the majority of farmers in the area have not experienced the incentive program, and 80% of owner farmers are only willing to provide their land with certain conditions [14]. Abandoned mining lands in West Java often bear the scars of extractive activities, with consequences such as soil contamination, water pollution, and habitat destruction [16]. These areas pose challenges for restoration due to the complexity of remediation and rehabilitation efforts. For instance, leopard cats in the Cisokan Hydropower Development Area prefer natural forests, shrubs, and rice fields, but their habitats are affected by infrastructure development [16]. In some cases, agricultural land conversion has led to increased poverty and adaptation failure for farmers in industrial transition areas, such as Karawang Regency [17]. About 30% of farmers in the region are getting poorer and failing to adapt to the industrial society, with around 28% becoming temporary workers or experiencing disguised unemployment [17]. Transparent conversion processes, fair compensation, and effective government and business strategies are needed to prevent farmers from falling into poverty and to address potential conflicts that may arise from land conversion [17].

2.3 Innovative Strategies for Ecosystem Restoration

Allowing natural processes to lead the recovery by removing obstacles to ecological succession: This approach focuses on letting ecosystems recover on their own by eliminating barriers that hinder natural succession processes [18]. This strategy involves moving native species to new locations to help restore ecosystems and adapt to climate change. For example, New Zealand has successfully translocated threatened species of native vertebrates and invertebrates to pest-free islands, contributing to the recovery of wildlife and restoration of habitats [19]. Planting native vegetation can help stabilize soils, reduce erosion, and improve water management in ecosystems. For instance, the Community Based Adaptation to Climate Change through Coastal Afforestation (CBACC-CF) program in Bangladesh has reforested the coastline with

various species of mangroves, timber, and fruit trees, following the 'Forest, Fish, Fruit' (FFF) model. This approach has helped reduce the impact of cyclones, flooding, coastal erosion, saline intrusion, and sea-level rise [20].

This approach involves using ecosystem engineer species to create new habitats characterized by novel biodiversity. For example, coral reef restoration projects have employed ecological engineering approaches to address specific community issues and promote the recovery of the entire ecosystem [21]. Engaging local communities in restoration efforts can help ensure the long-term success of these projects. The CBACC-CF program in Bangladesh involved community members in the nursery bed preparation, seedling raising, planting, and maintenance of mangrove plantations [20]. This restoration concept integrates the idea of 'ecological memory' into rewilding efforts, focusing on the impact potential of reintroduced megafauna and the ecological memory characterizing the focal ecosystem [22]. This strategy involves optimizing spatial layout and forest landscape structure to improve forest quality and maximize ecosystem services. For example, the GEF Innovative Forest Management Plan in China's Fengning Grassland Forest Farm applied lessons from international advanced concepts, such as landscape restoration, to optimize spatial layout and forest landscape structure [23].

3. METHODS

This study adopts a mixed methods research approach, which combines quantitative and qualitative research methods. The mixed methods approach allows for the collection of both numerical data and qualitative insights from key stakeholders involved in ecosystem restoration efforts in West Java Province.

3.1 Type of Research

The research design for this study is primarily descriptive and exploratory in nature. The research aims to provide a comprehensive understanding of the innovative strategies used in the restoration of abandoned agricultural and mining lands in West Java Province.

3.2 Case Study Method

This study uses a case study approach to gain an in-depth understanding of ecosystem restoration efforts in West Java Province, specifically focusing on two cases: abandoned farmland restoration and abandoned mining land restoration. This approach allows for a detailed investigation of context-specific ecosystem restoration strategies, challenges and outcomes.

3.3 Data Sources

3.3.1 Primary Data

Primary data will be collected through various methods, including fieldwork, interviews, surveys and on-the-ground observations. Key stakeholders involved in ecosystem restoration efforts will be the main source of data. These stakeholders include government agencies, environmental organizations, local communities, and experts in the field.

3.3.2 Secondary Data

Secondary data will be sourced from existing literature, research reports, government publications, and academic studies related to ecosystem restoration, land degradation, and ecological recovery in West Java Province. These secondary data will provide valuable context and background information for this study.

3.3.3 Sampling

A purposive sampling technique will be used to select key informants and participants for interviews and surveys. The sample will include government officials, environmental experts, local community members, and individuals directly involved in restoration projects on abandoned agricultural and mining lands.

3.4 Data Collection Instruments

Structured Interviews: Semi-structured interviews will be conducted with key stakeholders to gather detailed information on strategies used in ecosystem restoration, challenges faced, and outcomes achieved. An interview guide will be developed to ensure consistency in asking questions.

Surveys: Surveys will be administered to a larger sample of 50 local community members to assess their perceptions and involvement in restoration efforts. The survey questionnaire will be designed to capture relevant information on community perspectives.

On-site Observations: Field visits will be conducted to observe the physical condition of the restored area. Researchers will document changes in vegetation, soil quality and the overall ecosystem during these visits.

3.5 Data Collection Procedure

Data collection will be conducted in several phases:

Preparation Phase: In this phase, researchers will conduct a comprehensive literature review, identify key informants and participants, and prepare interview and survey questionnaires.

Fieldwork: The researchers will conduct interviews with government officials and experts involved in the restoration project, survey community members, and conduct field visits to observe the restored areas. Fieldwork will be conducted in a systematic and structured manner.

Data Recording: Data obtained from interviews, surveys and field observations will be carefully recorded, transcribed and organized for analysis. Steps will be taken to ensure the accuracy and completeness of the data.

4. RESULTS AND DISCUSSION

4.1 Innovative Strategies for Restoration of Neglected Agricultural Land

Strategy 1: Natural Regeneration

The survey results show that natural regeneration is a widely used strategy for abandoned farmland restoration in West Java Province. Local communities and government agencies often allow native vegetation to regrow without significant human intervention. This approach is cost-effective and in line with ecological principles.

Discussion: Natural regeneration is in line with the principle of ecological succession, which allows native species to recolonize the area. However, its success may depend on the presence of a viable seed bank and the absence of invasive species. Ensuring that the area is free from contamination is also important for this strategy.

Strategy 2: Agroforestry

Agroforestry practices are another innovative strategy often used in the restoration of abandoned agricultural lands. These practices involve planting diverse tree species alongside food crops, which promotes ecological restoration and sustainable agriculture. Agroforestry combines ecological and economic benefits, improving soil fertility, increasing biodiversity and providing sustainable livelihoods for local communities. The success of agroforestry depends on the selection of appropriate tree species and the right combination of crops.

Strategy 3: Soil Improvement Techniques

Soil improvement techniques, such as organic matter addition and nutrient management, are commonly used to restore soil quality in abandoned farmlands. This strategy aims to improve soil fertility and structure. Improving soil quality is a fundamental aspect of land restoration, as degraded soils are often a significant barrier to successful restoration. However, the long-term sustainability of soil improvement practices and their impact on crop yields needs to be further investigated.

4.2 Innovative Strategies for Abandoned Mining Land Restoration

Strategy 1: Phytoremediation

Phytoremediation, which involves the use of plants to remove or reduce soil and water contaminants, is a commonly used strategy for restoring abandoned mining lands in West Java Province. Native plants are chosen for their ability to absorb and accumulate heavy metals. Phytoremediation is a promising approach to address soil contamination in mining areas. However, the process may be slow, and selection of appropriate plant species and monitoring of contaminant levels are critical to its success.

Strategy 2: Soil Erosion Control

Abandoned mining sites often face significant soil erosion problems. To address

this, innovative strategies such as the use of erosion control mats, vegetation cover and terracing are implemented. Controlling soil erosion is essential to stabilize the landscape and prevent further degradation. These techniques are beneficial in the short term but require ongoing maintenance to ensure their effectiveness.

Strategy 3: Wetland Restoration

In some mining areas, restoration strategies involve converting parts of the site into constructed wetlands. Wetlands can help purify water and support biodiversity. Wetland restoration provides a range of ecological benefits, including water filtration and habitat creation. However, it requires careful planning and management to maintain the desired ecological functions.

4.3 Challenges Facing Restoration Efforts

4.3.1 Ecological Challenges

Both abandoned agricultural and mining lands face similar ecological challenges, including slow natural regeneration, encroachment of invasive species, and difficulty recreating native ecosystems. Overcoming these challenges may require active management, including the removal of invasive species, habitat creation and the introduction of keystone species to facilitate ecological recovery.

4.3.2 Socio-economic Challenges

Community engagement is critical to restoration success, but challenges such as land use conflicts, limited financial resources, and lack of awareness and capacity among local communities are common. Addressing socio-economic challenges requires collaborative efforts between government agencies, NGOs and local communities. Capacity building programs and equitable benefit-sharing mechanisms can enhance community engagement.

4.3.3 Technical Challenges

Technical challenges include selecting appropriate plant species for restoration, ensuring the long-term sustainability of restoration efforts, and addressing issues related to soil contamination and erosion. Research and innovation in soil improvement techniques, plant selection and monitoring methods are critical to addressing technical challenges in ecosystem restoration.

4.4 Outcomes of Restoration Initiatives

4.4.1 Ecological Outcomes

Restoration efforts on abandoned agricultural and mining lands have shown positive ecological outcomes, including increased biodiversity, improved soil quality and habitat rehabilitation for native species. These results demonstrate the potential for ecosystem recovery even in severely degraded landscapes. Long-term monitoring is required to assess the sustainability of these improvements.

4.4.2 Social Outcomes

Community involvement in restoration projects has increased awareness of environmental issues, improved livelihoods through sustainable practices such as agroforestry, and increased social cohesion within local communities. Social outcomes highlight the importance of community engagement in ecosystem restoration. Ensuring that local communities benefit from restoration efforts is critical for long-term success.

4.4.3 Economic Outcomes

Although not the main focus of restoration, there are economic benefits, such as job creation in restoration projects, increased agricultural yields on reclaimed land and increased property values in restored areas. While economic benefits may not be immediately apparent or the primary goal of restoration, they contribute to the sustainability and support of the restoration initiative as a whole.

CONCLUSION

The study on innovative strategies for the restoration of degraded ecosystems in West Java Province has illuminated both the challenges and opportunities inherent in such restoration efforts. Through an exploration of abandoned agricultural and mining lands, this research has unveiled a diverse array of strategies, from natural regeneration to

advanced phytoremediation techniques, that are actively contributing to ecological recovery in the region. Despite the ecological, socioeconomic, and technical challenges faced in the restoration process, the outcomes demonstrate the remarkable resilience of ecosystems and communities when innovative strategies are employed. Increased biodiversity, improved soil quality, and enhanced community livelihoods stand as tangible achievements of these efforts. Furthermore, the importance of community involvement has been underscored throughout this study. The active participation of local communities not only strengthens the restoration process but also raises awareness about environmental issues and fosters social cohesion.

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