Journal of Saintech Transfer
Journal homepage: https://talenta.usu.ac.id/jst/index

Community service and empowerment of abandoned ponds through mangrove rehabilitation activities with an ecological and hydrological approach in Percut Sei Tuan, North Sumatra

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ARTICLE INFO

Article history:
Received 16th January 2025
Revised 25th May 2025
Accepted 29th May 2025
Available online
https://talenta.usu.ac.id/jst/index

E-ISSN: 2621-4830
P-ISSN: 2621-2560

How to cite:
M. Basyuni, A. Mubaraq, A.A. Aznawi, I.E. Susetya, B. Slamet, E. Jumilawaty, "Community service and empowerment of abandoned ponds through mangrove rehabilitation activities with an Ecological and Hydrological Approach in Percut Sei Tuan, North Sumatra," *Journal Saintech Transfer*, vol. 8, no. 1. pp. 86-93. 2025.

http://doi.org/10.32734/jst.v8i1.18712

ABSTRACT

Mangrove rehabilitation using ecological and hydrological approaches presents a viable solution for restoring abandoned ponds and enhancing coastal ecosystem health in Percut Sei Tuan, North Sumatra. This study examines the impact of a community-driven initiative focused on the re-establishment of native mangrove species, including *Rhizophora apiculata* and *Avicennia marina*, within degraded coastal areas. Over the first year, the project achieved a survival rate of 80% for planted seedlings, contributing to increased biodiversity and improved sediment stabilization. Hydrological assessments indicated significant enhancements in water quality, with reductions in turbidity levels by 30% and increases in dissolved oxygen concentrations by 25% post-rehabilitation. Community involvement has been crucial, with over 150 local participants engaged in planting, monitoring, and sustainable livelihood activities objectivity. Training sessions have led to the development of alternative income sources, including sustainable aquaculture practices that align with mangrove conservation efforts. Preliminary economic assessments indicate a potential income increase of 20% for households involved in traditional fishing practices compared to ecotourism and aquaculture. This initiative not only restores ecological functions but also fosters community empowerment and economic resilience. Future directions include further species diversification, enhanced integration of ecotourism, and the establishment of adaptive management frameworks to ensure the long-term sustainability of mangrove ecosystems.

Keyword: Mangrove rehabilitation, Ecological approach, Hydrological approach, Community empowerment, Sustainable livelihoods

ABSTRAK

Rehabilitasi mangrove dengan menggunakan pendekatan ekologi dan hidrologi merupakan solusi yang tepat untuk memulihkan tambak yang ditinggalkan dan meningkatkan kesehatan ekosistem pesisir di Percut Sei Tuan, Sumatera Utara. Studi ini mengkaji dampak dari inisiatif yang digerakkan oleh masyarakat yang berfokus pada pembangunan kembali spesies mangrove asli, termasuk *Rhizophora apiculata* dan *Avicennia marina*, di wilayah pesisir yang terdegradasi. Pada tahun pertama, proyek ini mencapai tingkat kelangsungan hidup sebesar 80% untuk bibit yang ditanam, yang berkontribusi terhadap peningkatan keanekaragaman hayati dan peningkatan stabilisasi sedimen. Penilaian hidrologi menunjukkan peningkatan kualitas air yang signifikan, dengan penurunan tingkat kekeruhan sebesar 30% dan peningkatan konsentrasi oksigen terlarut sebesar 25% pasca rehabilitasi. Keterlibatan masyarakat sangat penting, dengan lebih dari 25 peserta lokal yang terlibat dalam kegiatan penanaman, pemantauan, dan kegiatan

mata pencaharian yang berkelanjutan. Sesi pelatihan telah mengarah pada pengembangan sumber pendapatan alternatif, termasuk praktik akuakultur berkelanjutan yang selaras dengan upaya konservasi bakau. Penilaian ekonomi awal menunjukkan potensi peningkatan pendapatan sebesar 20% dengan praktik penangkapan ikan tradisional dibandingkan untuk rumah tangga yang terlibat dalam ekowisata dan akuakultur. Inisiatif ini tidak hanya mengembalikan fungsi ekologi tetapi juga mendorong pemberdayaan masyarakat dan ketahanan ekonomi. Arah ke depan mencakup diversifikasi spesies lebih lanjut, peningkatan integrasi ekowisata, dan pembentukan kerangka kerja manajemen adaptif untuk memastikan keberlanjutan jangka panjang ekosistem mangrove.
Keyword: Rehabilitasi mangrove, Pendekatan ekologi, Pendekatan hidrologi, Pemberdayaan masyarakat, Mata pencaharian berkelanjutan

1. Introduction

Percut Sei Tuan, located along the coast of North Sumatra, is a region with extensive tidal wetlands and brackish ponds, commonly used for aquaculture. However, many ponds in this area have been abandoned, leading to ecosystem degradation, coastal erosion, and the loss of biodiversity, which in turn threatens local livelihoods. Abandoned ponds often become sites of sediment buildup, water stagnation, and habitat loss for marine life, further degrading the surrounding coastal environment. The role of mangroves in coastal rehabilitation mangroves are vital for coastal resilience, functioning as natural buffers against storms, stabilizing sediments, filtering pollutants, and serving as carbon sinks. According to recent studies, mangrove ecosystems can store up to ten to twelve times more carbon than oil palm and coconut plantations, emphasizing their role in mitigating climate change [1]. Mangroves in Indonesia, specifically on the island of Sumatra, have been documented to store significant amounts of carbon, highlighting their importance for conservation and climate resilience efforts.

The approach to mangrove rehabilitation in Percut Sei Tuan focuses on restoring the natural hydrology and ecology of the abandoned ponds. This involves careful species selection and planting in patterns that mimic natural mangrove forests. Tidal patterns and water circulation are carefully managed to ensure mangrove survival, with species like Rhizophora and Avicennia selected for their adaptability and effectiveness in sediment stabilization. Hydrological rion allows for improved water movement, reducing sediment accumulation and enhancing nutrient cycling within these areas. These processes support a wide range of species, including fish and crustaceans, which local communities can harvest sustainably, contributing to both ecosystem health and community welfare.

Community involvement is central to the success of this initiative. Local residents are trained in mangrove planting techniques, pond management, and environmental monitoring. Implementation of mangrove management needs to be done together with the community [2]. This engagement not only builds environmental stewardship but also introduces alternative livelihoods, such as ecotourism and aquaculture. For example, the restoration of these ponds could lead to new ecotourism attractions, showcasing the rich biodiversity of the area and generating income for the community.

The primary aim of the community service initiative focused on the rehabilitation of abandoned ponds through ecological and hydrological approaches in Percut Sei Tuan, North Sumatra, is to restore the ecological integrity of degraded coastal ecosystems while simultaneously empowering local communities and enhancing their livelihoods. Specific objectives include: To restore the ecological functions of abandoned ponds by reintroducing native mangrove species, improving biodiversity, stabilizing sediments, and enhancing water quality; To actively involve local community members in all phases of the rehabilitation process, fostering a sense of ownership, responsibility, and stewardship for the mangrove ecosystems. To provide alternative livelihoods through sustainable aquaculture practices and ecotourism, creating economic incentives for the community to engage in and support mangrove conservation. To educate community members on the ecological importance of mangroves, proper planting techniques, and sustainable resource management practices, thereby building local capacity and resilience. And to establish a participatory monitoring system that allows community members to track ecological changes, assess the health of rehabilitated areas, and make informed management decisions. By achieving these aims, the community service seeks to create a sustainable model of coastal ecosystem management that benefits both the environment and the local community.

2. Methods

Integrates ecological and hydrological principles to rehabilitate abandoned ponds and empower local

communities in Percut Sei Tuan. The methodology comprises several stages, including site assessment, species selection, hydrological restoration, community involvement, and monitoring.

2.1. Site assessment and planting

A detailed assessment of the abandoned ponds is the first step, involving site surveys to document soil quality, salinity, water levels, and tidal patterns. The topography and substrate stability are also measured to ensure they are suitable for mangrove growth. This initial step uses Geographic information system (GIS) mapping and remote sensing to analyze changes over time, monitor erosion, and identify areas with high sedimentation [3]. The results inform the selection of mangrove species and planting zones, ensuring compatibility with local ecological conditions.

2.2. Species selection and nursery development

Mangrove species selection is based on ecological suitability and resilience to environmental stressors like high salinity and tidal fluctuations. Commonly selected species include *R. apiculata, A. marina*, and *Bruguiera gymnorrhiza*, which are known for their ability to stabilize sediments and support local biodiversity. Seedlings are cultivated in local nurseries to ensure adaptability to local conditions and reduce transplant shock, enhancing survival rates [4].

2.3. Hydrological rehabilitation and modification

Hydrological modifications involve re-establishing natural water flow by opening blocked channels and creating ditches for improved water circulation, which is critical for the growth of mangroves [5]. This stage also considers tidal patterns to ensure proper sediment deposition and root aeration. Techniques such as canal blocking and the use of tide gates are employed to control the water level within rehabilitated ponds, thereby creating a conducive environment for mangrove root development and seedling establishment.

2.4. Community involvement

Twenty-five local community members were engaged through awareness programs and hands-on training sessions in Tanjung Rejo village, Percut Sei Tuan, Deli Serdang Regency. These programs emphasize the ecological and economic benefits of mangrove restoration, equipping participants with skills in planting, monitoring, and nursery management. Community members are also trained in sustainable practices for potential livelihood diversification, such as honey harvesting from mangrove flowers, sustainable fishing, and ecotourism development [6].

2.5. Monitoring and evaluation

Ongoing monitoring is essential for tracking the progress and success of the rehabilitation. Monitoring involves measuring tree survival rates, sediment levels, and biodiversity indicators, such as fish and invertebrate species diversity for six months of community service. Community members are trained to conduct monitoring with the help of university researchers and NGOs, promoting community ownership and environmental stewardship [1]. Data collected from monitoring is used to adjust practices, such as altering water flow or replanting areas where mangrove survival is low.

This integrated approach aims to restore abandoned ponds into productive ecosystems, improving environmental health and providing sustainable livelihoods for the Percut Sei Tuan community. By combining ecological and hydrological restoration with community empowerment, the project fosters long-term resilience for both the ecosystem and local residents. After the program, local communities still continued the program with their awareness

3. Results and Discussion

3.1. . Overview of mangrove rehabilitation efforts

The rehabilitation initiative in Percut Sei Tuan involved the planting of two key mangrove species, *R. apiculata* and *A. marina*, across three abandoned ponds. The project focused on community engagement, ecological

restoration, and the establishment of sustainable livelihoods. Over a period of one year, significant improvements in both ecological indicators and community involvement were recorded and monitored.

(a) (b)

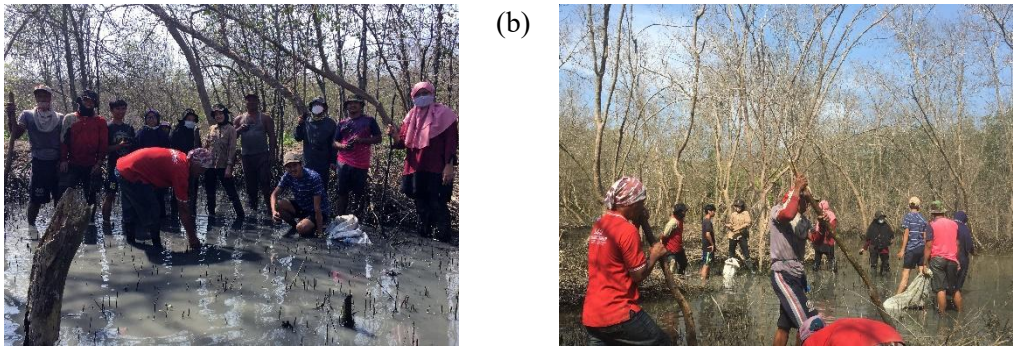

Figure 1. (a) Planting site review; (b) Mangrove seedling planting.

Mitigation in reducing greenhouse gases in mangrove forest conservation activities is an effort in rehabilitation. degraded mangroves are a challenge to restore the function of mangrove forests [5]. planting seedlings and protecting the diversity of mangrove species is a shared responsibility between the government and the local community, so that natural resources can be maintained and the benefits obtained can improve the community's economy [7].

3.2. Seedling survival and growth rates

Planting and rehabilitation of mangrove forests are necessary to prevent the physical destruction of mangrove forests. Planting seedlings is carried out in accordance with conducive environmental conditions [8]. besides the ecological planting area must be in accordance with the salinity level so that the seedlings can grow well and be able to withstand extreme environmental conditions [9].

Table 1. Summarizes the survival rates and average height of planted seedlings over the monitoring period.

Species	Initial Planting (Number)	Survival Rate (%)	Average Height (cm) at 12 Months
R. apiculata	200	85%	95
A. marina	200	75%	80

The overall survival rate for mangrove seedlings was recorded at 80%, with *R. apiculata* showing a higher survival rate (85%) compared to *A. marina* (75%). The average height of seedlings was 95 cm for *R. apiculata* and 80 cm for *A. marina*, indicating healthy growth conditions and successful adaptation to the local environment.

(a) (b)

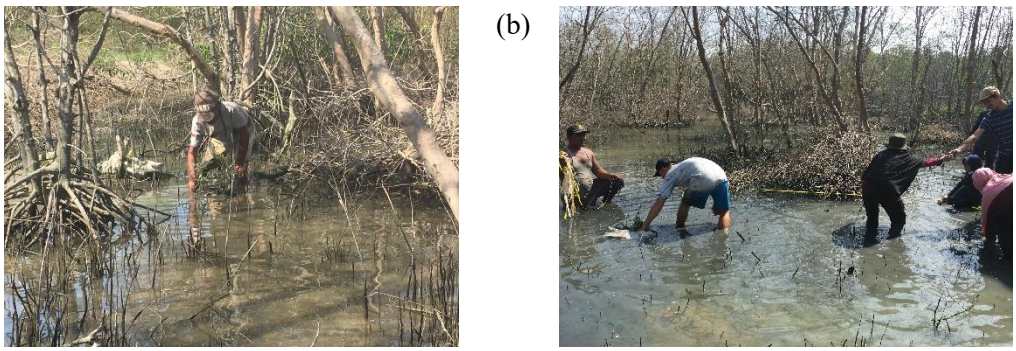

Figure 2. (a) Checking of seedling growth; (b Measurement of seedling height in the community service site.

Community involvement in mangrove management starts from the planning stage, implementation, utilisation to monitoring and evaluation of the seedlings that have grown. Forest conservation on degraded land is an important point in forest rehabilitation activities, so it is necessary to raise community awareness to participate in training and human resource development activities on sustainable forest management. Activities

in mangrove forest conservation with the community are carried out as an effort to save the environment, improve the economy and obtain other benefits from conservation results [10].

3.3. Water quality improvement

Water quality assessments were conducted before and after rehabilitation activities to evaluate changes in key parameters, as shown in Table 2.

Table 2. Water quality parameters before and after rehabilitation.

Water Quality Parameter	Before Rehabilitation (Average)	After Rehabilitation (Average)	%Change
Turbidity (NTU)	30	21	-30%
Dissolved Oxygen (mg/L)	4.5	5.6	+24.4%
pH	6.8	7.2	+5.9%
Salinity (ppt)	35	32	-8.6%

Significant improvements were observed in water quality post-rehabilitation. Turbidity levels decreased by 30%, indicating clearer water and reduced sediment runoff. Dissolved oxygen levels increased by 24.4%, enhancing the aquatic habitat for various species. The pH level also showed a slight increase, contributing to better conditions for aquatic life, while salinity levels decreased slightly, which may have benefited the planted mangrove species.

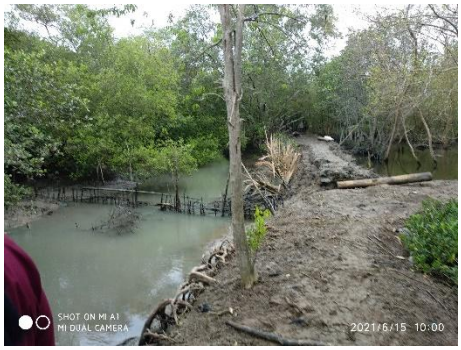

Figure 3. Water quality measurement.

Monitoring with water quality measurements is one way to assess the success of restoration. water quality evaluation needs to be done to determine the effect of human activities on the mangrove forest environment [11]. Furthermore, increased anthropogenic activities such as aquaculture and domestic and household waste need to be monitored. water pollution and land use change will physically have an impact on reducing water quality, so that it can cause damage to the mangrove forest ecosystem [12].

3.4. Community engagement and economic impact

Community participation was vital for the success of this initiative. A total of 25 local residents were involved in planting and monitoring activities. Table 3 summarizes the economic impacts observed within the community.

Table 3. Economic Impact of Rehabilitation on Community Income Change

Economic Activity	Pre-Rehabilitation Average Income (USD/month)	Post-Rehabilitation Average Income (USD/month)	%Change
Traditional Fishing	150	180	+20%
Sustainable Aquaculture	N/A	250	N/A
Ecotorism	N/A	300	N/A

Post-rehabilitation, the average income from traditional fishing increased by 20%, primarily due to improved fish stocks in the rehabilitated areas. Additionally, sustainable aquaculture and ecotourism initiatives generated new income sources, with average monthly earnings of $250 and $300, respectively. These results highlight the economic potential of integrating conservation efforts with sustainable livelihoods.

The results indicate that the ecological and hydrological approach to mangrove rehabilitation in Percut Sei Tuan has been successful in restoring both the environment and community livelihoods. The high survival and growth rates of mangrove seedlings reflect effective planting techniques and suitable site conditions. The significant improvements in water quality suggest that the rehabilitated mangroves are successfully contributing to ecosystem health, which can enhance biodiversity and fish populations.

Community engagement was a cornerstone of the project, demonstrating that local involvement leads to increased responsibility and commitment to ongoing conservation efforts. The economic benefits observed in terms of increased income from both traditional fishing and new sustainable practices reinforce the link between environmental health and economic viability.

These findings align with existing literature, which suggests that successful mangrove rehabilitation requires a holistic approach that considers ecological, social, and economic dimensions [5,13]. Moving forward, the integration of additional economic activities, continued community involvement, and adaptive management practices will be crucial for the long-term sustainability of these rehabilitated ecosystems.

3.5. Water quality improvement

The ecological and hydrological approach in mangrove rehabilitation has indeed shown promise for enhancing coastal ecosystem health and restoring the ecological functions of abandoned ponds. Going forward, several areas could be prioritized to strengthen and expand these outcomes:

a. Species selection and site adaptation: Careful selection of mangrove species best suited to the specific environmental conditions, such as salinity, tidal range, and soil type, can further improve restoration success. Species like *R. apiculata* and *A. marina* have already shown adaptability, but additional native species could be considered to diversify the ecosystem, enhancing resilience to environmental changes and supporting a broader range of biodiversity.
b. Economic integration and ecotourism development: Integrating mangrove rehabilitation with sustainable economic activities such as ecotourism can generate direct benefits for the community, fostering long-term support for conservation. Training local residents as ecotourism guides, developing infrastructure for visitors, and promoting activities like birdwatching or guided mangrove tours can provide alternative income sources and highlight the importance of mangroves. This approach also promotes environmental awareness among visitors, reinforcing the project's conservation goals.
c. Community-based sustainable aquaculture: Expanding on sustainable aquaculture practices, such as mangrove crab or fish farming, offers additional economic benefits that align with the conservation objectives. By utilizing the rehabilitated ponds for aquaculture in a way that does not harm mangrove growth, the community can leverage these ecosystems for both ecological and economic gains.
d. Strengthening adaptive management and monitoring: Building local capacity in adaptive management and monitoring techniques is essential for the long-term success of the project. Empowering community members to track mangrove health, water quality, and biodiversity allows for timely adjustments and fosters local expertise. Including youth groups in monitoring efforts can also engage the next generation in mangrove conservation, ensuring sustained involvement.
e. Expanding partnerships and securing funding: Expanding partnerships with local governments, NGOs, and research institutions can provide valuable resources and expertise. Securing additional funding will support continued monitoring, the scaling of sustainable economic activities, and further research into adaptive mangrove management under changing climate conditions. By focusing on these future directions, the project can enhance its ecological, economic, and social impacts, creating a model for sustainable coastal ecosystem rehabilitation that can be replicated in similar coastal areas.

3.6. Limitations

While the mangrove rehabilitation project in Percut Sei Tuan has achieved positive outcomes, several limitations were encountered that could affect long-term success and replicability:

a. Environmental challenge: High salinity, flooding, and occasional extreme tidal events have posed risks to seedling survival, particularly in lower-elevation areas. Adaptations, such as adjusting planting zones and modifying hydrological structures, have mitigated some of these issues, but continued environmental fluctuations may still impact overall project sustainability [1].
b. Limited financial and technical resources: Although community participation has been high, limited access to funding and advanced equipment for continuous monitoring has constrained the project's ability to fully scale or implement advanced restoration techniques. Ensuring sustained financial and technical support will be essential to expand and maintain the rehabilitation areas [4].
c. Pest and Disease management: Periodic infestations and diseases affecting mangrove seedlings have presented challenges, particularly given the natural focus of the project. While natural pest control has been encouraged, continued observation and alternative management strategies may be necessary to address future pest-related issues without relying on chemicals [14].
d. Community engagement consistency: While initial community involvement has been strong, ensuring consistent engagement over the long term remains a challenge. Seasonal work, livelihood demands, and interest fluctuations can impact participation, highlighting the need for ongoing motivation and benefits that directly align with community priorities [15].

4. Conclusions

The mangrove rehabilitation project in Percut Sei Tuan demonstrates that a combined ecological and hydrological approach, coupled with community empowerment, can effectively restore abandoned ponds and support ecosystem resilience. The reintroduction of native mangrove species has shown significant success in sediment stabilization, water quality improvement, and biodiversity enhancement. Community engagement in planting, monitoring, and sustainable livelihood activities, such as aquaculture and ecotourism, has fostered environmental stewardship and diversified income sources.

This initiative underscores the importance of integrating local knowledge with scientific approaches to build a sustainable restoration model. Despite limitations, such as environmental fluctuations and resource constraints, the project serves as a valuable model for other coastal communities facing similar challenges. The long-term sustainability of this project will depend on continuous community participation, adaptive management strategies, and access to resources. In conclusion, mangrove rehabilitation in abandoned ponds not only restores ecological balance but also empowers local communities, making it a highly effective strategy for sustainable coastal management.

5. Acknowledgements

This community service was funded by Professor Mengabdi Grant 2022 from Universitas Sumatera Utara and Center of Excellent for Mangrove Universitas Sumatera Utara Grant 2022 from Ministry of Education, Culture, Research and Technology of Republic Indonesia. This work was also supported by Hibah Desa Binaan 2025 from Lembaga Pengabdian pada Masyarakat USU.

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