Institute of Research and Publication Indonesia
CONSEN: Indonesian Journal of Community Services and Engagement
Journal Homepage: https://journal.irpi.or.id/index.php/consen
Vol. 5 Iss. 2 November 2025, pp: 182-191
P-ISSN: 2828-9943 E-ISSN: 2809-0217

Community Empowerment of Perlis Village, West Brandan, Langkat through Mangrove Restoration and Clean Water Supply Activities

Pemberdayaan Masyarakat Desa Perlis, Brandan Barat, Langkat melalui Kegiatan Pemulihan Mangrove dan Penyediaan Air Bersih

Mohammad Basyuni [1,2*], Alfian Mubaraq [1,3], Andi Aznan Aznawi [1,3], Astrid Fauzia Dewinta[1,4], Irvan [5], Julia Syahriani Hasibuan [1,4], Itchika Sivaipram [6], Venus E Leopardas[7], OK Hasnanda Syahputra[1,3], Netti Herlina Siregar[1,5], Oke Rina Ramayani[8], Yunilda Andriyani[8], Nurdin Sulistiyono[1,2]

[1]Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan 20155, Indonesia
[2]Department of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan 20155, Indonesia
[3]Graduate School of Agricultural Sciences, Faculty of Agriculture, Universitas Sumatera Utara, Medan 20155, Indonesia
[4]Department of Aquatic Resources Management, Faculty of Agriculture, Universitas Sumatera Utara, Medan 20155, Indonesia
[5]Faculty of Engineering, Universitas Sumatera Utara, Medan 20155, Indonesia
[6]Faculty of Science, Chulalongkorn University, Bangkok, Thailand
[7]College of Marine and Allied Sciences, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines
[8]Faculty of Medicine, Universitas Sumatera Utara, Medan 20155, Indonesia

E-Mail: m.basyuni@usu.ac.id

Makalah: Diterima 18 July 2025; Diperbaiki 15 October 2025; Disetujui 15 November 2025
Corresponding Author: Mohammad Basyuni

Abstrak

Degradasi hutan mangrove di Desa Perlis, Brandan Barat, Langkat akibat penebangan liar, konversi lahan, dan intrusi air laut telah menimbulkan tantangan ekologi dan sosial ekonomi yang serius. Kegiatan ini bertujuan memulihkan ekosistem mangrove yang rusak serta meningkatkan akses masyarakat terhadap air bersih melalui pendekatan partisipatif. Aktivitas meliputi pelibatan masyarakat, pelatihan peningkatan kapasitas, penanaman mangrove di kawasan pesisir terdegradasi, serta pembangunan sistem penyediaan air bersih. Proyek ini berhasil memulihkan lima hektar hutan mangrove dengan tingkat hidup bibit 85% dan meningkatkan akses air bersih rumah tangga dari 40% menjadi 85%. Hasil tersebut berdampak pada peningkatan keanekaragaman hayati, pengurangan erosi pantai, serta peningkatan kesehatan dan kesejahteraan masyarakat. Inisiatif ini menunjukkan bahwa integrasi antara pemulihan ekologi dan pengembangan infrastruktur dapat memperkuat pemberdayaan masyarakat pesisir serta mendukung pencapaian Tujuan Pembangunan Berkelanjutan (TPB 6, 13, 14, dan 15).

Keyword: Pemulihan mangrove, pemberdayaan komunitas, akses air bersih, pendekatan partisipatif.

Abstract

Mangrove degradation in Perlis Village, West Brandan, Langkat, caused by illegal logging, land conversion, and seawater intrusion, has led to serious ecological and socio-economic challenges. This project aimed to restore degraded mangrove ecosystems and improve community access to clean water through a participatory approach. Activities included community engagement, capacity-building workshops, mangrove planting on degraded coastal areas, and the installation of a clean water supply system. The project successfully restored five hectares of mangrove forest with an 85% sapling survival rate and increased clean water access from 40% to 85% of households. These outcomes improved local biodiversity, reduced coastal erosion, and enhanced community health and livelihoods. The initiative

demonstrates that integrating ecological restoration with infrastructure development can effectively empower coastal communities and contribute to sustainable development goals (SDGs 6, 13, 14, and 15)

Keyword: Mangrove restoration, community empowerment, clean water access, participatory approach

1. Introduction

The main drivers of mangrove deforestation in North Sumatra are the clearing of mangrove forests for land use, primarily for ponds and oil palm plantations [1-3]. To address the loss of these valuable ecosystems, policy makers and the research community have introduced and encouraged restoration efforts around the world. One of the main motivations for mangrove restoration is to restore the high value of mangrove ecosystems for biodiversity and diverse ecosystem services such as coastal protection, improved fish products, and other products that directly and indirectly benefit local and global populations. Deforestation has negatively impacted 16% of the world's endangered mangrove forests [3] and reduced mangrove biodiversity and carbon storage in forest biomass [4]. Mangrove deforestation globally has led to a significant loss of forest area and contributed to biomass decline and carbon release to the atmosphere [5]. Mangrove conservation and sustainable mangrove management are needed to maintain mangrove forests and enhance reforestation programs. While global and regional mangrove deforestation is well documented [6], deforestation and reforestation due to land use and land cover change are rarely reported, especially at the district level in Indonesia [7]. Sustainable management of mangrove ecosystems requires an ecological approach that considers biogeochemical processes such as carbon and nitrogen cycling, which can aid in natural climate change mitigation [8].

In North Sumatra, mangrove restoration has become a key national priority. Indonesia's Mangrove and Peatland Restoration Agency (BRGM) has targeted the rehabilitation of 600,000 hectares of degraded mangroves by 2024, with North Sumatra listed as one of the top priority provinces. Previous analyses revealed that deforestation rates in districts such as Serdang Bedagai, Labuhanbatu, and Deli Serdang reached approximately 1–2% annually, resulting in significant losses of forest biomass and carbon storage [2,5]. Mangrove loss not only contributes to greenhouse gas emissions but also weakens the socio-ecological resilience of coastal communities [6,8]. Community empowerment plays a vital role in ensuring the sustainability of restoration initiatives. Integrating ecological rehabilitation with livelihood development and access to basic needs such as clean water can strengthen local ownership and long-term impact. Previous studies across Indonesia show that community-based ecotourism, waste management, and village water projects have improved both environmental conditions and local welfare [9–11]. In Perlis Village, West Brandan, Langkat, similar community-driven programs have supported transitions from traditional fishing toward diversified livelihoods such as aquaculture, seafood processing, and mangrove ecotourism [12-14]. Despite these efforts, access to clean water remains limited, posing challenges for public health and daily productivity—especially for women and children who are primarily responsible for water collection. These initiatives demonstrate the importance of community involvement in achieving sustainable rural development and improved quality of life [15-18].

This community service aims to demonstrate how participatory mangrove restoration and the establishment of a clean water supply system can enhance the resilience and well-being of the Perlis Village community. Specifically, it examines: (1) the effectiveness of community participation in ecosystem rehabilitation; (2) the environmental, social, and economic outcomes of integrated restoration programs; and (3) the potential for scaling up such initiatives to align with Indonesia's Sustainable Development Goals (SDGs 6, 13, 14, and 15). By connecting ecological restoration and community empowerment, this project provides an applicable model for sustainable coastal development that can be replicated in other regions of Indonesia and beyond.

2. Materials and Method

The community empowerment project in Perlis Village demonstrated that combining ecological restoration with clean water infrastructure can create significant environmental and social benefits. Restoring five hectares of mangroves improved coastal resilience and biodiversity, while clean water access enhanced public health and reduced gendered labor burdens. Active community participation throughout planning, implementation, and monitoring strengthened local ownership and long-term sustainability.

2.1 Community Engagement and Capacity Building

To foster a sense of ownership and responsibility, the first step involved engaging the local community in the planning and decision-making processes. Participatory rural appraisal (PRA) methods were used to understand the community's needs, prioritize objectives, and design. activities that align with local aspirations. This technique allows community members to voice their concerns and be active participants in shaping the interventions.

Workshops and training sessions were organized to build the community's capacity in both mangrove restoration and water management. These sessions included hands-on demonstrations for planting mangroves and operating and maintaining the water supply systems. Research shows that building local knowledge and technical skills is key to ensuring the long-term success of community-based environmental projects.

2.2 Mangrove Restoration Activities

The mangrove restoration method involved a combination of ecological and community-based approaches. Mangrove saplings, sourced from local nurseries, were planted along degraded coastal areas in collaboration with environmental organizations. Techniques such as site selection based on tidal patterns and the careful choice of species were guided by best practices for coastal ecosystem restoration [14,15, 19]. The community took on the responsibility for the upkeep and monitoring of the restoration efforts, conducting regular inspections to assess sapling survival rates and manage threats, such as erosion or illegal logging. Involving local stakeholders in monitoring activities has been shown to significantly improve the effectiveness and sustainability of restoration efforts. The steps taken in the restoration activity are:

2.2.1 Seedling, Species Selection and Planting

In this restoration activity, species selection is based on pioneer species. The preliminary survey shows that in the service site, it is known that the diversity of mangrove species that grow are: *Avicennia alba, A marina, A officinalis* (family Avicenniaceae) and Rhizophora spp (*Rhizophora apiculata*, *R. mucronata, R. stylosa*). From field observations, the mangrove ecosystem is dominated by the Acanthaceae and Rhizophoraceae families. Therefore, the species used for rehabilitation activities are *Avicennia* spp. and *Rhizophora* spp.

Based on the fact that the site to be rehabilitated is located on the sea shore due to abrasion and wave action, nursery establishment should be carried out. In addition, there are many trees/fruits around the planting site. The existence of a nursery will be especially beneficial when planting during the off-peak fruiting season or when replanting. In addition, planting from seeded fruit will result in a high percentage of growth. Seedlings should be available one day prior to planting. This activity is particularly useful for mangrove species such as Avicennia spp (Figure 1).

Figure 1. Mangrove nursery activities for restoration

2.2.2 Selection of nursery/nursery site

The nursery site should be located on flat and level ground. In addition, nursery sites in crab areas or easily accessible to goats should be avoided. The nursery site should be as close as possible to the planting site and should be flooded by the tide at least 20 times per month to avoid watering the seedlings [19].The size of the nursery depends on the number of fruits to be seeded. Bamboo can be used as the material for the nursery. The roof/shade can be made of nipa leaves or alang-alang with a height between 1-2 meters. Nursery beds vary in size according to need, but are generally 5 x 1 m in size. A 5 x 1 meter bed can hold [19].

2.3 Establishment of Clean Water Supply System

To address water scarcity, a clean water supply system was developed using participatory engineering methods. Local residents collaborated with external engineers and water resource experts to design a system tailored to the village's geography and needs. This involved installing pipelines, storage tanks, and distribution points at key locations within the village. Research on rural water projects highlights the importance of involving community members in the design and construction phases to ensure that systems are culturally appropriate

and easily maintainable. In addition, training on system maintenance was provided to selected community members, ensuring that they have the technical skills required for long-term operation. According to studies on rural water infrastructure, the sustainability of such systems is heavily dependent on local capacity for operation and maintenance [20].

2.4 Environmental Education and Advocacy

The project integrated environmental education programs aimed at raising awareness about the importance of mangrove ecosystems and clean water. Schools and community centers were used as venues to conduct educational workshops for both children and adults. These workshops were designed to encourage environmental stewardship and foster a conservation mindset among villagers. Dushkova 2024 [21] indicates that integrating environmental education into community empowerment projects increases the likelihood of long-term environmental sustainability. Advocacy efforts were also launched to secure government support and alignment with regional environmental policies. By positioning the project within the framework of national coastal management and water security initiatives, the community was able to attract additional resources and institutional backing.

2.5 Monitoring and Evaluation

A continuous monitoring and evaluation (M&E) system was put in place to assess the progress of both the mangrove restoration and clean water supply activities. This involved setting up key performance indicators (KPIs) such as the survival rate of mangrove saplings, improvements in water access, and reductions in waterborne diseases within the community. Participatory monitoring, where community members are directly involved in data collection and analysis, was central to this process.

Regular feedback loops between the villagers and project facilitators allowed for adaptive management, enabling adjustments to be made in response to challenges encountered during the project's implementation. Research shows that participatory M&E is essential for the sustainability of community-driven development projects, as it builds local capacity while ensuring that interventions are responsive to emerging needs [22].

3. Results and Discussion

The project in Perlis Village led to measurable improvements in both environmental and social outcomes, particularly in mangrove restoration and clean water supply. The results from the mangrove restoration and clean water supply activities demonstrate the transformative impact of community-based interventions.

3.1 Synergies between Mangrove Restoration and Livelihoods

The restoration of 5 hectares of mangroves not only improved coastal resilience but also had direct economic benefits for the local population. The increase in fish populations reported by local fishers is a significant outcome, as mangroves provide critical habitats for juvenile fish and other marine species. This aligns with research showing that healthy mangroves can boost fishery productivity and contribute to the livelihoods of coastal communities. In addition, the community's involvement in both planting and maintaining the mangroves has fostered a strong sense of environmental stewardship. Over 90% of villagers expressed a willingness to continue expanding and caring for the restored areas, suggesting that the project has successfully instilled long-term commitment to conservation.

Table 1. Mangrove ecosystem restoration

Indicator	Pre-Project Status	Post-Project Status	Impact
Area of mangrove restoration	0 hectares	5 hectares	Successful replanting of degraded coastal areas.
Mangrove sapling survival rate	N/A	85%	High survival rate due to regular community monitoring.
Coastal erosion reduction	High vulnerability	Reduced vulnerability	Mangrove restoration decreased erosion
Biodiversity (e.g., fish species)	Declining fish stocks	Increasing fish population	Local fishers reported higher fish catches

The restoration of 5 hectares of mangroves resulted in significant ecological benefits, particularly in reducing coastal erosion and increasing marine biodiversity. The survival rate of saplings (85%) is notable, indicating that community-based monitoring and maintenance played a crucial role in ensuring the success of the project (Table 1). Another study conducted in Demak, Indonesia showed the importance of participatory mapping of ecosystem services to improve community-based mangrove rehabilitation and management. The

study results show that active involvement of local communities in mangrove mapping and management can improve the effectiveness of mangrove ecosystem rehabilitation and sustainability [23].

3.2 Sustainability of the Clean Water Supply System

The clean water supply system has proven to be highly effective in meeting the village's needs. The increased coverage from 40% to 85% of households, combined with the reduction in time spent fetching water, has had a profound impact on daily life. Women and children, who traditionally bore the responsibility for collecting water, now spend less time on this task, allowing more time for education and income-generating activities. This outcome mirrors findings from studies on the role of water access in improving gender equity and economic development [15,18].

Figure 2. Discussion with the head of Perlis Village and preparation for the borehole construction

Table 2. Impact of clean water supply system in Perlis Village

Indikacor	Pre-Project Status	Post-Project Status	Impact
Access to clean water	40% of households	85% of households	Significant increase in water access.
Time spent fetching water	2-3 hours per day	30 minutes per day	Reduced time burden, especially for women and children.
Waterborne Ddsease incidence	Frequent cases of diarrhea	50% reduction in reported cases	Marked improvement in community health.
Household water consumption	30 liters/day	60 liters/day	Increased availability and usage of clean water.

Preparations have been made by holding discussions with the village head and partners for the provision of clean water (Figure 2). The clean water supply system successfully improved access for 85% of households in Perlis Village. Prior to the project, only 40% of households had access to clean water, and villagers, especially women, had to spend significant time fetching water. The project has also led to a 50% reduction in waterborne diseases, highlighting the health benefits of improved water access (Table 2).

Figure 3. The water from the borehole is crystal clear

Figure 3 showed the results of the borehole water after conducting training with the community. The training of local residents to maintain the water system is another key factor in its sustainability. By building local capacity, the village is now self-reliant in managing the system, reducing the need for external technical assistance. Research on community-managed water systems supports the notion that local ownership and capacity-building are crucial to ensuring long-term sustainability [23]. This is similar to community-based research in Srogol Village, Bogor District, which showed that active community participation in water resources management improved the sustainability of the system. Local capacity building through training and direct involvement contributes to village self-reliance in managing water systems, reducing reliance on external technical assistance [24].

3.3 Challenges and Adaptions

While the overall results were positive, the project faced several challenges. In the case of the mangrove restoration, occasional storm surges damaged some newly planted saplings, particularly in low-lying areas. To address this, the community implemented adaptive measures such as building protective barriers around vulnerable sections. Similar experiences in other coastal restoration projects show that adaptive management is key to dealing with environmental uncertainties. In terms of the clean water supply, some households initially struggled to access the new distribution points. This issue was addressed by extending the pipeline network and installing additional water storage tanks. Ensuring equitable access to clean water is essential for community-wide benefits, as research shows that uneven access can lead to social tensions.

Despite the positive outcomes of the project, several limitations were identified during the implementation and evaluation phases. Understanding these limitations is essential for improving future community empowerment initiatives and ensuring more robust, sustainable outcomes.

3.3.1 Environmental and Ecological Challenges

While the mangrove restoration was largely successful, environmental factors such as unpredictable weather patterns posed challenges that affected the project's progress. For example, storm surges in the region occasionally damaged newly planted mangrove saplings, leading to setbacks in restoration efforts. These challenges highlight the importance of adaptive management and the need for continuous monitoring to address external environmental threats.

Table 3. Challenges and mitigation strategies in mangrove restoration

Limitation	Description	Impact	Mitigation Strategy
Unpredictable weather patterns	Storm surges damaged newly planted mangrove saplings.	Reduced sapling survival rates in low-lying areas, slowing restoration.	Use of protective barriers and strategic planting in less vulnerable areas.

Lack of species diversity in planting	Limited variety of mangrove species used in restoration.	Potential risk of reduced ecosystem resilience to pests and diseases.	Introduction of more diverse species in future planting phases.

In terms of species diversity, the initial focus was on planting the most common mangrove species available locally. However, relying on a narrow range of species can reduce ecosystem resilience, making the restored areas more vulnerable to disease outbreaks or changing environmental conditions. This limitation could be mitigated by diversifying the species used in future restoration phases (Table 3).

3.3.2 Technical and Infrastructure Limitations

While the clean water supply system was a significant improvement for the village, certain technical and infrastructural limitations were encountered. For instance, some households in more remote areas of the village still had limited access to water due to the location of distribution points. In addition, the village's capacity to handle future maintenance challenges may be limited without ongoing technical support.

Table 4. Water supply project limitations and mitigation strategies

Limitation	Description	Impact	Mitigation Strategy
Uneven water access	Remote households experienced limited access to water distribution points.	Reduced benefits for some parts of the village.	Expansion of pipeline network and additional distribution points.
Limited technical expertise for maintenance	Community members trained but may lack expertise for complex repairs.	Risk of system breakdown if complex technical issues arise.	Continued technical training and establishment of partnerships with local authorities for support.

The project provided basic technical training to a select group of community members, but the expertise required for long-term, complex maintenance is still lacking. While routine maintenance can be handled by the community, more advanced technical issues might require external assistance. This limitation points to the need for ongoing capacity building and establishing partnerships with local authorities or organizations that can provide technical support (Table 4).

3.3.3 Social and Cultural Limitations

Social dynamics and cultural perceptions also presented challenges during the project. While the project actively involved community members in decision-making and implementation, not all segments of the population were equally engaged. Women and marginalized groups, for example, faced barriers to full participation in certain aspects of the project, such as decision-making roles or technical training sessions.

Table 5. Social limitations and mitigation strategies

Limitation	Description	Impact	Mitigation Strategy
Limited participation of women	Women's participation in technical training and decision-making was lower.	Reduced empowerment and capacity building for women in technical aspects.	Tailored training programs and more inclusive decision-making processes.
Marginalized groups' engagement	Certain marginalized groups were less involved in decision-making.	Inequitable distribution of project benefits and involvement.	Ensure representation of all community segments in future initiatives.

Although women were actively engaged in water collection and household-level activities, their participation in technical and leadership roles remained limited. This reflects broader social and cultural dynamics in the community, where prevailing gender norms may restrict women's involvement in technical and decision-making processes. Similar patterns have been observed in other rural empowerment projects, where women's contributions are often undervalued despite their central role in household and resource management [18]. Tailoring training programs to be more inclusive and ensuring the participation of women and marginalized groups in planning and implementation stages are essential for achieving equitable benefits and strengthening community resilience [21]. Tailoring training programs to be more inclusive and increasing

efforts to involve women and marginalized groups in decision-making will be essential for ensuring that the benefits of the project are equitably shared (Table 5).

3.3.4 Financial and Resource Constraints

The long-term sustainability of the project is dependent on financial and resource availability. While the community has taken significant ownership of the mangrove restoration and water supply system, there are concerns about the availability of financial resources for ongoing maintenance and future expansion. Previous studies emphasize that sustainable rural water infrastructure and community-based environmental programs require reliable funding mechanisms, institutional support, and local technical capacity to ensure long-term functionality [20,24].

Table 6. Financial limitations and project sustainability strategy

Limitation	Description	Impact	Mitigation Strategy
Limited financial resources	Community lacks sufficient funding for long-term maintenance and expansion.	Potential future breakdowns in infrastructure without adequate resources.	Establish partnerships with NGOs and government for long-term support.
Dependence on external funding	Project implementation relied on external funding sources.	Sustainability could be affected if funding is not continued.	Develop local revenue-generating activities linked to environmental conservation (e.g., eco-tourism).

Without secure financial resources, maintaining the infrastructure—both the mangroves and water supply system—could be difficult. The initial funding came from external sources, but reliance on external support poses a risk if future funds are not secured. The community will need to explore revenue-generating activities, such as eco-tourism or government grants, to ensure long-term sustainability (Table 6).

3.4 Broader Implications for Community Empowerment

The project in Perlis Village underscores the significance of an integrated and participatory approach to community empowerment. By combining environmental restoration with essential infrastructure development, the initiative successfully generated both ecological and social benefits for local residents. The participatory design—emphasizing community involvement in decision-making, planning, and implementation—proved fundamental in fostering local ownership and accountability.

Moreover, aligning project objectives with national and regional frameworks for coastal management and water security enabled the community to attract institutional support and strengthen long-term sustainability. This synergy between local action and broader policy priorities reflects the importance of multi-level governance in achieving effective and resilient community development [9,10]. Previous research has shown that such integrated, community-driven approaches can enhance local adaptive capacity, promote sustainable resource use, and accelerate progress toward the Sustainable Development Goals (SDGs) [21,23].

4. Conclusion

The community empowerment project in Perlis Village demonstrated that combining ecological restoration with clean water infrastructure can create significant environmental and social benefits. Restoring five hectares of mangroves improved coastal resilience and biodiversity, while clean water access enhanced public health and reduced gendered labor burdens. Active community participation throughout planning, implementation, and monitoring strengthened local ownership and long-term sustainability.

To strengthen the long-term resilience of the initiative, several strategic actions are recommended. First, integrating the project within local government programs and national initiatives on mangrove restoration and rural infrastructure will ensure institutional continuity and policy support. Second, promoting eco-based economic activities—such as mangrove ecotourism and sustainable fisheries—can provide new income opportunities for residents while reinforcing environmental conservation. Finally, continuous capacity building for technical maintenance and adaptive management is essential to equip community members with the skills needed to respond effectively to future environmental challenges. Collectively, these strategies can serve as a replicable model for other coastal communities in Indonesia seeking to balance ecological rehabilitation with socio-economic empowerment.

The limitations of the project highlight the complexities involved in community-based initiatives. While the outcomes of the mangrove restoration and clean water supply activities were largely positive, challenges related to environmental factors, infrastructure limitations, social dynamics, and financial sustainability remain.

Addressing these limitations through adaptive management, continued technical support, and more inclusive approaches will be essential for the long-term success of the project.

5. Acknowledgments

This community service was funded by Professor Mengabdi Grant 2021 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.

References

[1] M. Basyuni *et al.*, "Mangrove Biodiversity, Conservation and Roles for Livelihoods in Indonesia," in *Mangroves: Biodiversity, Livelihoods and Conservation*, Singapore: Springer Nature Singapore, 2022, pp. 397–445. doi: 10.1007/978-981-19-0519-3_16.

[2] M. Basyuni and N. Sulistiyono, "Deforestation and reforestation analysis from land-use changes in North Sumatran Mangroves, 1990-2015," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 309, no. 1, 2018, doi: 10.1088/1757-899X/309/1/012018.

[3] D. R. Richards and D. A. Friess, "Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 113, no. 2, pp. 344–349, 2016, doi: 10.1073/pnas.1510272113.

[4] A. Mubaraq *et al.*, "Diversity and distribution of nitrifying bacteria play an important role in the nitrogen cycle in mangrove sediments," *Glob. J. Environ. Sci. Manag.*, vol. 10, no. 4, pp. 2145–2162, 2024, doi: 10.22034/gjesm.2024.04.39.

[5] C. J. Wong *et al.*, "Estimating Mangrove above-ground biomass loss due to deforestation in Malaysian Northern Borneo between 2000 and 2015 using SRTM and landsat images," *Forests*, vol. 11, no. 9, 2020, doi: 10.3390/F11091018.

[6] L. Goldberg, D. Lagomasino, N. Thomas, and T. Fatoyinbo, "Global declines in human- driven mangrove loss," *Glob. Chang. Biol.*, vol. 26, no. 10, pp. 5844–5855, Oct. 2020, doi: 10.1111/gcb.15275.

[7] M. Ilman, P. Dargusch, P. Dart, and Onrizal, "A historical analysis of the drivers of loss and degradation of Indonesia's mangroves," *Land use policy*, vol. 54, pp. 448–459, Jul. 2016, doi: 10.1016/j.landusepol.2016.03.010.

[8] A. Mubaraq, A. A. Aznawi, M. Basyuni, and I. Sivaipram, "Carbon and Nitrogen Management in Mangrove Ecosystems in Reducing Greenhouse Gas Emissions: Ecological and Islamic Perspective," *Islam. Res.*, vol. 7, no. 2, pp. 113–120, 2024, doi: 10.47076/jkpis.v7i2.323.

[9] A. C. W. Tomo *et al.*, "Empowering Communities through Innovative Programs: A Review of Village Tourism Program and Integrated Waste Management," *Int. J. Eng. Bus. Soc. Sci.*, vol. 2, no. 01, pp. 713–722, 2023, doi: 10.58451/ijebss.v2i01.103.

[10] F. Rianto, B. Jenawi, and R. Sujarwani, "Pemberdayaan Masyarakat Melalui Ekowisata pada Desa Pesisir di Kabupaten Bintan," *JPM (Jurnal Pemberdaya. Masyarakat)*, vol. 6, no. 1, pp. 623–631, 2021, doi: 10.21067/jpm.v6i1.4049.

[11] A. Wondirad and B. Ewnetu, "Community participation in tourism development as a tool to foster sustainable land and resource use practices in a national park milieu," *Land use policy*, vol. 88, no. August, p. 104155, 2019, doi: 10.1016/j.landusepol.2019.104155.

[12] F. Insani, I. Harahap, and R. Syahriza, "Analisis Pemberdayaan Ekonomi Masyarakat Pesisir di Desa Perlis Kecamatan Brandan Barat Kabupaten Langkat," *Ganaya J. Ilmu Sos. dan Hum.*, vol. 7, no. 3, pp. 153–163, 2024, doi: 10.37329/ganaya.v7i3.3338.

[13] A. H. P. Hamzah, N. Nurhasanah, R. Nurul, and H. R. Effendi, "Training and Empowerment of Marunda Coastal Communities regarding Introduction to Types and Planting of Mangroves in North Jakarta," *Amalee Indones. J. Community Res. Engagem.*, vol. 5, no. 1, pp. 183–196, 2024, doi: 10.37680/amalee.v5i1.4247.

[14] S. Sumarmi *et al.*, "Mangrove Forest Management Strategy in Bedul, Banyuwangi: Collaboration Between Community and Alas Purwo National Park for Sustainable Ecotourism Development," *Geoj. Tour. Geosites*, vol. 52, no. 1, pp. 85–97, 2024, doi: 10.30892/gtg.52108-1185.

[15] S. Sukamta, S. Sudarja, B. Nurrahman, B. Paripurna Kamiel, and S. Sudarisman, "Peningkatan Kemandirian Desa Melalui Pembangunan Instalasi Perpipaan Air Bersih dari Sumber Mata Air ke Rumah Penduduk," *BERDIKARI J. Inov. dan Penerapan Ipteks*, vol. 7, no. 1, 2019, doi: 10.18196/bdr.7152.

[16] L. Collins, D. McGregor, S. Allen, C. Murray, and C. Metcalfe, "Source water protection planning for Ontario First Nations communities: Case studies identifying challenges and outcomes," *Water (Switzerland)*, vol. 9, no. 7, pp. 1–19, 2017, doi: 10.3390/w9070550.

[17] N. Hadiyanti, A. D. Pamujiati, and N. Lisanty, "Sistem Budidaya Lahan Kering Dan Pemanfaatan Pekarangan Di Desa Kuncir Kabupaten Nganjuk," *JMM - J. Masy. Merdeka*, vol. 4, no. 1, 2021, doi: 10.51213/jmm.v4i1.63.

[18] S. L. Rautanen, B. van Koppen, and N. Wagle, "Community-driven multiple use water services: Lessons learned by the rural village water resources management project in nepal," *Water Altern.*, vol. 7, no. 1, pp. 160–177, 2014.
[19] M. Basyuni, P. Yani, and K. S. Hartini, "Evaluation of mangrove management through community-based silvofishery in North Sumatra, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 122, no. 1, 2018, doi: 10.1088/1755-1315/122/1/012109.
[20] P. Moriarty, S. Smits, J. Butterworth, and R. Franceys, "Trends in rural water supply: Towards a service delivery approach," *Water Altern.*, vol. 6, no. 3, pp. 329–349, 2013.
[21] D. Dushkova and O. Ivlieva, "Empowering Communities to Act for a Change: A Review of the Community Empowerment Programs towards Sustainability and Resilience," *Sustain.*, vol. 16, no. 19, 2024, doi: 10.3390/su16198700.
[22] N. Sangole, S. Kaaria, J. Njuki, K. Lewa, and M. Mapila, "Community based participatory monitoring and evaluation: Impacts on farmer organization functioning, social capital and accountability," *J. Rural Community Dev.*, vol. 9, no. 2, pp. 128–148, 2014.
[23] E. Damastuti and R. de Groot, "Participatory ecosystem service mapping to enhance community-based mangrove rehabilitation and management in Demak, Indonesia," *Reg. Environ. Chang.*, vol. 19, no. 1, pp. 65–78, 2019, doi: 10.1007/s10113-018-1378-7.
[24] R. A. Hafidh, I. Widianingsih, and A. Buchari, "The Practice of Community-Based Water Resource Management in Rural Indonesia," *J. Gov.*, vol. 6, no. 2, 2021, doi: 10.31506/jog.v6i2.11994