ENGAGEMENT
Jurnal Pengabdian kepada Masyarakat
Vol. 09, No. 02, November, 2025, pp. 385-399

IoT-Based Smart Mangrove Tourism: Innovations in Conservation and Community Empowerment at Petengoran Mangrove

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Article History:
Received: July 15th 2025
Revised: Sept 16th 2025
Accepted: Nov 30th 2025

Keywords: *Community empowerment, Digital promotion, Ecotourism, IoT, Mangrove conservation*

Abstract: *This community service program addressed the challenges of weak financial management and lack of technological innovation in the development of Petengoran mangrove ecotourism in Gebang Village, Lampung. The subject of this program is the Petengoran Mangrove Conservation Group and 35 village residents, including women, youth, and local leaders. The purpose was to strengthen community capacity in managing ecotourism through IoT-based monitoring and digital promotion. The method employed includes training sessions, IoT device installation, digital campaign assistance, pre-test and post-test evaluations, and collaborative mentoring between academia and the community. Results show significant improvements in participants' knowledge scores, increased engagement of women and youth in conservation activities, adoption of digital-based promotion strategies, enhanced organizational capacity, and stronger local leadership involvement. These outcomes highlight the contribution of integrated technological and social empowerment approaches in supporting sustainable mangrove-based ecotourism.*

Introduction

The Petengoran Mangrove Forest, located in Gebang Village, Teluk Pandan District, Pesawaran Regency, Lampung, is a potential ecotourism area managed by the local community through the Mangrove Conservation Group with support from the Village-Owned Enterprise (BUMDes) of Gebang. Its strategic location, close to Mutun Beach and Pahawang Island, combined with its rich biodiversity and coastal landscape,

offers high prospects for sustainable tourism development[1].

Despite this potential, mangrove ecosystems worldwide are increasingly under threat from land conversion, illegal logging, and coastal development, which weaken their ecological role as carbon sinks and natural barriers against abrasion and climate change[2]. Similar challenges occur in Indonesia, including Pesawaran Regency, where mangrove areas have been converted into shrimp ponds, settlements, and industrial zones without proper environmental impact assessments, causing severe ecosystem degradation[3]. At the Petengoran site, these pressures are clearly visible: the mangrove area lies adjacent to privately owned shrimp ponds and physical infrastructure for ecotourism such as jungle tracking paths and road access has been damaged by abrasion. These conditions not only exacerbate ecological vulnerability to flooding and erosion but also hinder the development of sustainable mangrove-based ecotourism.

The site's potential as an educational tourism destination has already gained international attention. For instance, the Asia Forest Institute and Seoul National University conducted a field visit with 20 students and one professor, underscoring both the ecological richness of the mangroves and the need for technological innovation to support conservation and tourism promotion. Yet, despite this recognition, the local economy remains fragile. Most Gebang residents work in informal sectors such as farming and fishing, with household incomes still below the regional minimum wage of IDR 2,715,000 per month. Tourism revenues are modest, estimated at around IDR 1–2 million per month depending on the season, based on community reports as no formal financial records are available.

This economic limitation is compounded by gaps in ecological awareness. Although the community acknowledges that mangroves protect the coastline from abrasion, many remain unaware of their critical role in supporting local livelihoods. Mangroves also serve as vital nursery grounds for shrimp, crabs, shellfish, and other economically valuable marine resources. Beyond fisheries, they help safeguard freshwater availability by preventing saltwater intrusion into groundwater, which is essential for daily life in coastal settlements. Additionally, mangroves provide key ecosystem services, including carbon sequestration, air purification, and natural filtration of waste and sediments, thereby maintaining overall environmental health. Without a clear understanding of these broader ecological–economic connections, conservation efforts risk being perceived as secondary rather than central to long-term community

[1] Alexander Sanjaya et al., "Program Pascasarjana Magister Ilmu Lingkungan, Universitas Lampung," in *Jurnal Hutan Tropis*, vol. 11, no. 4 (Cetak, 2023).

[2] Jing Jing Zhu and Bing Yan, "Blue Carbon Sink Function and Carbon Neutrality Potential of Mangroves," in *Science of the Total Environment*, vol. 822, preprint, 2022, https://doi.org/10.1016/j.scitotenv.2022.153438; E. M.A. Strain et al., "Assessing the Coastal Protection Services of Natural Mangrove Forests and Artificial Rock Revetments," *Ecosystem Services* 55 (2022), https://doi.org/10.1016/j.ecoser.2022.101429.

[3] Sanjaya et al., "Program Pascasarjana Magister Ilmu Lingkungan, Universitas Lampung."

welfare.

A major challenge at Petengoran Mangrove lies in limited digital promotion and low participation of women and youth in conservation activities. Promotional efforts are still largely informal, relying on word of mouth and sporadic use of social media, while digital skills and training opportunities remain scarce among community members. This lack of engagement has constrained the group's capacity to attract visitors and maintain active participation, particularly from younger generations and women. These challenges are further reflected in the management of tourism income. Visitors are currently asked to contribute a voluntary donation of IDR 15,000 per person, yet no formal records of income or expenditure are maintained. Consequently, when essential infrastructure—such as the wooden mangrove bridge—requires repair, the community often has to rely on self-funded initiatives. The assisted community partner, the Petengoran Mangrove Conservation Group, remains non-productive from a business perspective, with operations still conducted manually and no digital reservation platform or visitor database. These constraints have weakened group cohesion, leading several members to withdraw as tourist visits declined and income proved insufficient.

This community service program is designed as a direct response to the challenges faced by the Petengoran Mangrove community. To reduce dependence on voluntary donations and overcome the absence of structured financial management, the program introduces an Internet of Things (IoT)-based ecotourism system that enables real-time environmental monitoring while also showcasing academic support for Petengoran to visitors. The use of IoT technology is a unique selling point, as few mangrove forests in the region currently employ such tools, making Petengoran an innovative and attractive destination for both tourists and researchers. To address the limited promotion and declining tourist visits, digital platforms will be developed for reservations, visitor database management, and online marketing, further leveraging the credibility and visibility provided by academic collaboration. At the same time, tailored training modules will be delivered to strengthen community capacity in conservation practices, technology adoption, and digital entrepreneurship, thereby encouraging broader participation from women and youth. Through these integrated efforts, the long-term goal is to transform Petengoran into a smart ecotourism village that combines conservation and technology while fostering sustainable income generation. More specifically, the program seeks to: (1) strengthen the ecological function of mangroves as carbon sinks and coastal protectors (SDG 13), (2) support marine biodiversity conservation (SDG 14), and (3) bridge the digital and economic gap of rural communities through technology transfer and empowerment (SDG 10).

Method

The program will be implemented over eight months, combining technology introduction, capacity building, and community engagement. The stages are as follows:

Preparation Phase.

Coordination with village officials, the Petengoran Mangrove Preservation Group, and the Youth Organization (karang taruna) to ensure program alignment with community needs.

Baseline Assessment

Pre-test questionnaires will be administered to all participants to assess their initial knowledge of mangrove conservation, digital promotion, and financial management.

Capacity Building Workshops

- Participants include 35 representatives from six hamlets of Gebang Village, involving women, teenagers, and adults to ensure inclusivity.
- Topics covered: mangrove conservation awareness, IoT-based environmental monitoring, financial bookkeeping, and digital entrepreneurship.
- Digital promotion module: assisting the community in creating and managing an Instagram account (to complement existing Facebook use), designing sample flyers for visitors, and training on content planning to maintain consistent postings and improve engagement.
- The karang taruna will be directly involved in digital promotion and content management.

Community Socialization

A village-wide socialization event will be held with the participation of the Village Head to reinforce community support and ensure top-down endorsement of the initiative.

Follow-Up and Evaluation

- Post-tests will be conducted to measure improvements in participants' knowledge and skills.
- Regular mentoring sessions to support practical application, including assisting with online content creation and flyer distribution.
- Final evaluation of the IoT system and community promotion strategies to measure impact on tourism and community participation.

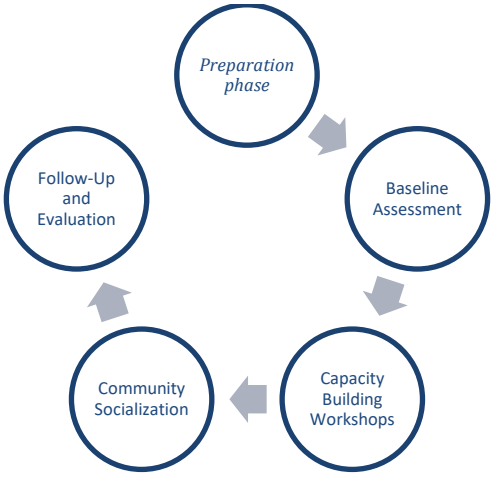

Figure 1. Methodological framework of the IoT-Based Smart Ecotourism Program

Result

The implementation of the IoT-Based Smart Mangrove Tourism program in Petengoran produced several tangible outcomes for the community. The assistance process was carried out step by step, starting with the installation of IoT devices for mangrove monitoring, followed by training sessions and support in digital promotion strategies. These activities actively involved the Petengoran Mangrove Group and 35 residents from six hamlets, with notable participation from women, youth, Karang Taruna, and the village government. Local leaders, including the Kepala Desa, also took part in the socialization and mentoring process, which further strengthened the sense of collective ownership and responsibility for the program.

Socially, the program triggered significant changes within the community. Awareness and participation of women and youth in mangrove conservation and ecotourism were enhanced, creating a more inclusive approach to environmental stewardship. The organizational capacity of the Petengoran Mangrove Group was strengthened, reducing dependency on voluntary donations and moving towards more structured financial sustainability. Digital-based promotion became a newly institutionalized practice, giving the community greater visibility to external stakeholders and visitors. Moreover, the involvement of the Kepala Desa in socialization and decision-making fostered stronger local leadership and legitimacy for the initiative.

The impact of the program could be identified through both quantitative and qualitative indicators. Pre- and post-test results demonstrated a measurable improvement in participants' knowledge and skills, while feedback from community members highlighted the usefulness of the training, particularly in terms of financial management and digital tools. Early outcomes also became visible in the form of increased engagement on social media platforms, smoother visitor information flow, and higher motivation among residents to develop and sustain mangrove-based ecotourism.

These results collectively show that the program not only improved technical capacity but also enhanced community empowerment and resilience for long-term conservation.

Table 1. Evaluation of Community Understanding on IoT Device Functions in Mangrove Monitoring

Question	Score Before	Percentage (%)	Score After	Percentage (%)
The temperature sensor in the IoT device can be used to monitor changes in water temperature in the mangrove ecosystem.	11	73.3	14	93.3
If the IoT device shows the water pH in the range of 6–8, the condition is still considered suitable for mangrove life.	10	66.7	13	86.7
The salinity sensor is useful for determining the salt content in the water, allowing detection of seawater or rainfall influence.	7	46.7	12	80
Data displayed by the IoT device can help managers make quick decisions in case of drastic changes in water quality.	13	86.7	15	100
The use of IoT makes it easier for the community to understand environmental conditions in real-time.	13	86.7	15	100

Discussion

The main objective of this community service program was to integrate Internet of Things (IoT)-based monitoring systems into mangrove ecotourism management while simultaneously empowering the local community of Petengoran. The results indicated successful installation of IoT devices, increased local participation, and initial improvements in awareness toward sustainable tourism practices. These factual outcomes serve as an entry point to theoretical analysis, where the role of technology adoption, community capacity building, and social transformation in rural coastal areas can be further explored.

Dynamics of the Community Service Process

The community service program began with an assessment of the needs of the Gebang Village community, particularly the Petengoran Mangrove Conservation Group. The team conducted this assessment through focus group discussions (FGDs), interviews with village officials, and field observations. The assessment results indicated that the partners' main challenges were weak financial management, minimal technological innovation, and limited digital promotion, which resulted in low tourist visits. Based on these needs, the community service team implemented a series of capacity-building activities. These activities included digital literacy training for ecotourism promotion, a simple financial management workshop, and assistance in using IoT devices to monitor the quality of the mangrove environment. In addition, the team provided digital assistance in the form of social media content creation and visitor database management. Then they designed this activity to be inclusive, involving women, youth, and youth organisations, thereby encouraging participation across various community groups. The approach used aligns with the principles of Participatory Rural Appraisal (PRA), which prioritises active community participation in program planning, implementation, and evaluation. Thus, the community becomes not only an object but also an empowered subject in the development of mangrove-based ecotourism.

Furthermore, the community empowerment model serves as the primary theoretical framework, where knowledge transfer, capacity building, and institutional strengthening are simultaneously implemented. Team found Similar practices in various environmental and ecotourism-based community service programs. For example, a study by Gunawan et al. emphasised the importance of enhancing community knowledge to support sustainable conservation[4], while research by Sanjaya et al. demonstrated the effectiveness of combining ecological training with technological innovation in strengthening village tourism institutions[5]. Therefore, this IoT-Based Smart Mangrove Tourism program offers practical relevance and contributions consistent with previous literature, but adds a unique feature in the form of integrating IoT technology and digital transformation into mangrove ecotourism management.

Knowledge and Capacity Improvement

Pre-test and post-test evaluation results showed significant improvements in participants' understanding of mangrove conservation, digital promotion, and group financial management. It demonstrates the effectiveness of the training approach,

[4] Hendra Gunawan, Mohammad Basyuni, Subarudi, Sri Suharti, Asihing Kustanti, Tien Wahyuni, Virni Budi Arifanti et al., "Empowering Conservation: The Transformative Role of Mangrove Education in Indonesia's Climate Strategies," *Forest Science and Technology* (2025): 3, https://doi.org/10.1080/21580103.2025.2519475.

[5] Sanjaya, Alexander, Christine Wulandari, Zainal Abidin, Rahmat Safe, Agus Setiawan, and Bainah Sari Dewi. "Judul Artikel di Sini." *Jurnal Hutan Tropis* 11, no. 4 (2023)

designed in accordance with Knowles' Adult Learning Theory, which emphasizes that adults learn best when learning materials are relevant to real needs, directly applicable, and provide practical benefits for everyday life. The participation of women and youth is a key factor in strengthening community capacity. Women play a crucial role in household socio-economic sustainability, preserving local knowledge, and managing community-based conservation activities. Youth, particularly youth groups, are taking on the role of agents of digital transformation through social media management, promotional content creation, and operating IoT devices. This dynamic aligns with gender and community development theory, where women and youth are not merely beneficiaries but also agents of change, accelerating social transformation. These findings align with a study by Harianto et al., which emphasized the need for a multidimensional empowerment strategy to address structural (access to capital, training, technology) and cultural (patriarchal norms) barriers. In the context of Petengoran, women's involvement in digital training and ecotourism promotion broadens their participation, while youth contribute to filling the technological gap[6]. Furthermore, research by Adhha et al. on coral transplant-based ecotourism revitalization in Pahawang shows that community participation—particularly through Village-Owned Enterprises (BumDes) and Tourism Groups (Pokdarwis)—can increase environmental awareness while strengthening the economic independence of tourist villages.[7] The active community involvement in the IoT-based innovative mangrove tourism program in Petengoran demonstrates the continuity of these findings, demonstrating that technology-based and social empowerment models can foster sustainable ecotourism. Thus, the increased capacity of participants is reflected not only in test scores but also in changes in social roles and inclusive participation. The integration of adult education, gender equality, and digital transformation makes this program a relevant and innovative community service model for supporting community-based ecotourism management.

Institutional Strengthening and Local Leadership

Community service activities demonstrate the emergence of a more systematic management pattern within the Petengoran mangrove group. Previously, conservation management was ad hoc and dependent on individual initiative. However, through mentoring, a more structured mechanism has been established, ranging from group financial records, role allocation in ecosystem maintenance, to a rotation system for ecotourism promotion. It reflects a shift towards more established, community-based

[6] Sugeng Harianto and Refti Handini Listyani, "Empowering Marginalised Women in Rural Indonesia: A Multifaceted Approach," *International Journal of Sociology and Social Policy* (2025): 4, https://doi.org/10.1108/IJSSP-02-2025-0111.

[7] Nurul Adhha, Novriadi Novriadi, Ahmad Fahmi, Alfon Hutapea, Taufik Azzahwa, and Khairurrijal Khairurrijal, "Revitalization of Ecotourism with Commercialization of Coral Transplantation Based on Productive Communities," *Widya Laksana* 13, no. 2 (2024): 266, https://doi.org/10.23887/jwl.v13i2.85180.

governance. The role of local leadership, particularly the Village Head and the Youth Organization (Karang Taruna), has proven significant. The Village Head serves as a linking capital, able to bridge the needs of community groups with support from the government and external institutions. Meanwhile, the Youth Organisation (Karang Taruna) serves as a driving force for innovation, particularly in digital promotion and the utilization of IoT technology, thereby enhancing the mangrove group's capacity to attract tourists and raise conservation awareness. The theoretical framework of local leadership explains that local leadership has the power to mobilize community participation, build legitimacy, and facilitate cross-stakeholder collaboration. When combined with social capital theory, this pattern shows that the success keys of conservation programs are a combination of bonding capital (internal cohesion of mangrove groups), bridging capital (networks between groups and Karang Taruna (youth organizations)), and linking capital (formal relationships with village government and external institutions). The classic literature by Putnam emphasizes that social capital—in the form of networks of trust and norms of reciprocity—is key to the success of community-based development[8]. Triyanti et al.'s study of mangrove-based coastal protection strategies in Demak also shows that the quality of bonding, bridging, and linking capital determines the effectiveness and inclusiveness of coastal ecosystem governance[9].

In the Petengoran context, support from the Village Head and Karang Taruna strengthened the quality of linking and bridging capital, making the mangrove group not only more solid internally but also more capable of accessing external resources. Thus, the sustainability of IoT-based mangrove ecotourism in Petengoran is not only determined by technology, but also by social capital and local leadership that encourage integration between ecological, social, and economic aspects.

Technology Adoption and Digital Transformation

The application of IoT to monitor the mangrove ecosystem in Petengoran is an example of the application of appropriate technology relevant to local needs. This system uses ESP8266-based sensors connected via cloud services to monitor temperature, humidity, and light intensity in real time. It strengthens the community's capacity for data-driven decision-making, in line with the findings of Antonova et al. that IoT technology integrated with cloud services can improve the efficiency of environmental monitoring while supporting conservation[10]. At the same time, there has been a shift in

[8] Robert D. Putnam, "Bowling Alone: America's Declining Social Capital," in *Culture and Politics: A Reader* (New York: Palgrave Macmillan US, 2000), 223

[9] Annisa Triyanti, Maarten Bavinck, Joyeeta Gupta, and Muh Aris Marfai, "Social Capital, Interactive Governance and Coastal Protection: The Effectiveness of Mangrove Ecosystem-Based Strategies in Promoting Inclusive Development in Demak, Indonesia," *Ocean & Coastal Management* 150 (2017): 4, https://doi.org/10.1016/j.ocecoaman.2017.10.017.

[10] Veronika M. Antonova, Elena E. Malikova, Alexey E. Panov, Igor V. Spichek, and Andrey Y. Malikov, "Implementation of IoT Technology for Data Monitoring via Cloud Services," *T-Comm: Telecommunications*

promotional media from conventional methods (printed posters and flyers) to digital platforms such as Instagram. This shift aligns with digital tourism theory, which emphasises the importance of digital transformation in expanding promotional reach and establishing the digital identity of tourist villages. A study by Saputra and Sanjiwani emphasised that community managerial readiness in managing digital tourism products is a critical factor for the success of a digitalisation strategy[11]. The Petengoran Youth Organisation (Karang Taruna) actively manages social media accounts and produces visual content about the mangrove ecotourism destination.Furthermore, digital innovation in ecotourism has strategic implications for sustainability. Eddyono et al. demonstrate that the e-ecotourism model can optimise the interaction between conservation[12], community participation, and strengthen the local economy. The integration of IoT and digital promotion in Petengoran has ecological (the availability of scientific data to maintain environmental carrying capacity), economic (increased tourist visits), and social (the active participation of women and youth in promotion and conservation) impacts.

Thus, the utilisation of IoT and digital promotion demonstrates that ecotourism sustainability depends not only on ecological conservation but also on the community's social and managerial readiness to adopt digital innovations. The integration of monitoring technology, social media, and the e-ecotourism model demonstrates the potential for transforming community-based tourism villages toward a more adaptive, inclusive, and sustainable direction.

Social Transformation and Sustainability

The implementation of the IoT-Based Smart Mangrove Tourism program in Petengoran has sparked a shift in public awareness of conservation. Previously, mangrove conservation was viewed merely as an ecological obligation; however, the community is now beginning to view it as both an economic asset and a collective identity. This transformation aligns with Rogers' theory of social change on the Diffusion of Innovation, where the adoption of innovations (whether in the form of IoT monitoring technology or digital promotional strategies) spreads through communication and interaction among community members[13]. Previously passive communities are

and Transport 15, no. 2 (2021): 47, https://doi.org/10.36724/2072-8735-2021-15-1-46-53.

[11] I. Gede Gian Saputra and Ni Made Gandhi Sanjiwani, "Digitalization of Rural Tourism Products: Evaluating Stages and Managerial Readiness," *International Journal of Human Research and Social Science Studies* 1, no. 6 (2024), https://doi.org/10.55677/ijhrsss/01-2024-Vol01I6.

[12] Fauziah Eddyono, Dudung Darusman, Ujang Sumarwan, and Tutut Sunarminto, "Optimization Model: The Innovation and Future of E-Ecotourism for Sustainability," *Journal of Tourism Futures* 11, no. 1 (2025): 98, https://doi.org/10.1108/JTF-03-2021-0067.

[13] Everett M. Rogers, Arvind Singhal, and Margaret M. Quinlan, "Diffusion of Innovations," in *An Integrated Approach to Communication Theory and Research* (New York: Routledge, 2014), 432, https://www.taylorfrancis.com/chapters/edit/10.4324/9780203887011-36/diffusion-innovations-everett-rogers-arvind-singhal-margaret-quinlan.

beginning to adopt new conservation practices, demonstrating a shift in collective norms and values. In this dynamic, women and youth play a role as agents of social change. Women contribute to managing household economic activities, internalising conservation values within their families, and participating in digital promotion. Meanwhile, youth, particularly youth groups in the Karang Taruna (Youth Organisation), are actively participating as early adopters in the use of social media and IoT devices.

Furthermore, this program demonstrates the integration of academia and the community as a form of mutually reinforcing collaboration. The involvement of teams of lecturers and students in technical assistance, digital training, and community-based research creates a knowledge co-production mechanism. It aligns with a study by Klerkx et al. , which demonstrated that collaboration between researchers and the community can accelerate the adoption of innovation through reciprocal interaction and knowledge exchange[14]. In the context of Indonesian higher education, this practice supports the achievement of higher education institutions' Key Performance Indicators (KPIs), particularly those related to tangible contributions to society. It aligns with the national development mission, Asta Cita, which emphasises strengthening research and innovation for the welfare of the people. The literature on community-based ecotourism development also emphasises that social transformation is key to sustainability. Ranjbar Motalegh shows that integrating cultural knowledge into tourism education can strengthen community identity and encourage community participation in sustainable practices[15]. Thus, the shift in conservation awareness in Petengoran is not only an ecological impact but also part of a broader social transformation, where technology, gender, education, and academic-community collaboration combine to strengthen community-based ecotourism.

Comparison with Previous Research and Uniqueness

Compared to previous research, the IoT-Based Smart Mangrove Tourism program in Petengoran has unique characteristics. Antonova et al.'s study on the application of IoT for cloud-based monitoring services demonstrated the technology's effectiveness in improving the efficiency of environmental data monitoring[16]. However, the research context was predominantly technical and did not directly integrate social aspects. Therefore, the program in Petengoran provides added value by not only adopting IoT

[14] Laurens Klerkx, Barbara Van Mierlo, and Cees Leeuwis, "Evolution of Systems Approaches to Agricultural Innovation: Concepts, Analysis and Interventions," in *Farming Systems Research into the 21st Century: The New Dynamic* (Dordrecht: Springer, 2012), 457.

[15] Faranak Ranjbar Motalegh, "Cultural Knowledge Integration in Tourism Higher Education," *International Journal of Tourism, Culture & Spirituality* 7, no. 2 (2024): 160, https://doi.org/10.22133/ijtcs.2025.503144.1196.

[16] Veronika M. Antonova, Elena E. Malikova, Alexey E. Panov, Igor V. Spichek, and Andrey Y. Malikov, "Implementation of IoT Technology for Data Monitoring via Cloud Services," *T-Comm: Telecommunications and Transport* 15, no. 2 (2021): 47, https://doi.org/10.36724/2072-8735-2021-15-1-46-53.

technology but also integrating it within a framework of community empowerment and sustainable ecotourism management. Conversely, research by Saputra and Sanjiwani emphasised the importance of managerial readiness in the digitalisation of rural tourism products[17]. They highlighted that the success of digital transformation is highly dependent on local institutional capacity. It aligns with the findings in Petengoran, but this program goes further by integrating direct digital literacy mentoring for youth and women, thereby building collective capacity to manage ecotourism promotion through social media. Furthermore, Eddyono et al. in their study of e-ecotourism models asserted that digital innovation is the future of sustainable ecotourism[18]. However, that study focused more on conceptual models and system optimization. At the same time, the Petengoran program presented concrete practices in the form of IoT integration, digital promotion, and strengthening local institutions as concrete manifestations of this idea.

From a social perspective, literature on women's empowerment through digital literacy emphasizes the relevance of women's participation in supporting the SDGs, particularly Goal 4 (quality education) and Goal 5 (gender equality). The Petengoran program adopted this approach, involving women not only as participants but also as active actors in internalizing the values of conservation and digital promotion. It distinguishes this program from previous community service studies, which often still position women as passive beneficiaries. Thus, the program's uniqueness lies in the simultaneous combination of three aspects: the application of IoT technology as appropriate technology, strengthening the digital capacity of the community (especially youth and women), and a gender-based, inclusive approach to ecotourism management. Multidimensional integration is found very rarely in previous research or community service programs, which typically focus on only one aspect of the issue. Therefore, the program in Petengoran is an innovative model for community-based ecotourism development in the era of digital transformation.

Conclusion

The implementation of the IoT-Based Smart Mangrove Tourism program at Petengoran demonstrates how the integration of technology, community empowerment, and inclusive social participation can create a sustainable model of ecotourism development. The introduction of IoT for environmental monitoring represents the adoption of appropriate technology that not only enhances conservation efforts but also strengthens community capacity to independently manage ecological resources. Meanwhile, the shift toward digital promotion through social media platforms has provided new opportunities for rural communities to expand their tourism markets in line with the framework of digital tourism transformation. Beyond technological

[17] Saputra and Sanjiwani, "Digitalization of Rural Tourism Products,"
[18] Eddyono et al., "Optimization Model,"

advancement, this program has succeeded in embedding social inclusivity by involving women and youth as active agents of change, thereby aligning with the global agenda of Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 5 (Gender Equality). Local leadership—embodied by the village head and karang taruna—proved essential in reinforcing social capital and ensuring continuity of initiatives. The combination of participatory approaches, adult learning theory, and community empowerment models underscores that meaningful transformation can only be achieved when communities are positioned not as passive recipients but as co-creators of innovation. Theoretically, this community service contributes to the literature by proposing a new model of community-based ecotourism empowerment that integrates technology, digital literacy, gender inclusivity, and local leadership. Practically, it strengthens the self-reliance of rural communities in sustaining mangrove-based ecotourism while offering replicable lessons for other coastal areas in Indonesia and beyond. By drawing together ecological conservation, technological innovation, and social transformation, this program provides a blueprint for how higher education institutions can fulfill their mandate to drive community empowerment while also advancing the Indikator Kinerja Utama (IKU) of universities and supporting the national Asta Cita vision.

Acknowledgements

The community service implemented by a team from the Sumatra Institute of Technology (Itera), to develop sustainable community-based mangrove ecotourism through IoT-based innovation, was funded by the Community Partnership Empowerment Grants Funding for Research and Community Service Programs for the 2025 Fiscal Year | Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, with the contract number: 3165/IT9.2.1/PM.01.06/2025. We would like to extend our sincere gratitude to all parties who have contributed to the success of this activity, particularly the community of Gebang Village, the Petengoran Mangrove Conservation Group, BUMDes, youth organizations, and the village government, for their outstanding support and collaboration. Our appreciation also goes to the Institute for Research and Community Service of the Sumatra Institute of Technology, the Directorate of Research, Technology, and Community Service, and the Directorate General of Higher Education, Science, and Technology, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, for providing financial and institutional support for the successful implementation of this program.

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