

THE ROLE OF ENVIRONMENTAL MANAGEMENT IN BUILDING RESILIENT URBAN COMMUNITIES THROUGH SUSTAINABLE GREEN ECONOMIC TRANSFORMATION

Editor: Prof. Dr. Eliana Sari
Dr. Khalilah Zakariya



**Proceeding of the International Conference on Environment,
Economics, Education, Social Humanities, and Technology
(ICE3SHT) 2025**

**THE ROLE OF ENVIRONMENTAL MANAGEMENT
IN BUILDING RESILIENT URBAN COMMUNITIES
THROUGH SUSTAINABLE GREEN ECONOMIC
TRANSFORMATION**

©UNJ Press, 2026

Editor

Prof. Dr. Eliana Sari

(Universitas Negeri Jakarta, Indonesia)

Dr. Khalilah Zakariya

(International Islamic University Malaysia, Malaysia)

ISBN: 978-634-294-005-1

Published 1 February 2026



UNJ PRESS

Gd. Ki Hajar Dewantara, Lantai 5, Kampus A

Universitas Negeri Jakarta

Jalan Rawamangun Muka, Rawamangun,

Pulo Gadung, Jakarta Timur, 13220

Indonesia

PREFACE

We are pleased to present the book Digital Innovation, Green Economy, and Environmental Sustainability for Resilient and Inclusive Development. This volume brings together scholarly contributions that address contemporary challenges related to digital transformation, sustainable development, and inclusive growth. The chapters in this book offer interdisciplinary perspectives that integrate digital innovation, education, economic dynamics, and environmental management, while aligning with the principles of the Sustainable Development Goals (SDGs). The work reflects both theoretical insights and empirical studies that are relevant to current academic and policy discussions. We extend our appreciation to all contributing authors for their valuable academic contributions. We hope this book serves as a useful reference for academics, researchers, students, practitioners, and policymakers engaged in sustainability and development studies.

Publisher

PROLOGUE

The contemporary world is undergoing a profound transformation driven by rapid digitalization, escalating environmental pressures, and shifting socio-economic structures. Digital technologies have become deeply embedded in everyday life, reshaping how individuals communicate, learn, govern, and conduct economic activities. At the same time, global challenges such as climate change, environmental degradation, social inequality, and economic uncertainty continue to intensify, exposing the limitations of conventional development models that prioritize growth without sustainability.

In this context, the pursuit of resilient and inclusive development has become an urgent global agenda. Innovation can no longer be understood solely in terms of technological advancement; it must also be evaluated through its social, economic, and environmental consequences. Similarly, sustainability is no longer confined to environmental protection alone, but encompasses human well-being, equity, education, governance, and community resilience. These interconnected challenges require integrated and interdisciplinary approaches that bridge digital innovation, green economic strategies, educational transformation, and environmental management.

This book is situated at the intersection of these critical issues. It brings together a collection of scholarly works that explore how digital innovation and technological change can be aligned with the principles of sustainability and inclusivity. The chapters examine diverse themes ranging from digital communication and collaborative innovation, educational leadership and quality assurance, green economy dynamics, smart technologies, to community-based environmental management and resilience. Collectively, they offer empirical evidence, theoretical reflections, and applied insights that highlight the role of digital transformation as both an opportunity and a challenge in achieving sustainable development.

A central premise of this volume is that sustainable and inclusive development cannot be achieved through isolated efforts or sectoral silos. Instead, it requires collaboration among governments, educational institutions, communities, industries, and civil society. Education plays a pivotal role in this process, serving as a catalyst for critical thinking, innovation, and value formation in the digital era. Likewise, green economy initiatives and environmentally responsible practices are

essential to ensuring that economic progress does not come at the expense of ecological integrity or social justice.

Aligned with the Sustainable Development Goals (SDGs), this book emphasizes the importance of integrating local contexts with global development frameworks. Many of the studies presented in this volume draw from experiences in emerging and developing regions, demonstrating how global sustainability agendas can be translated into practical strategies at the community, institutional, and policy levels.

These contributions underscore the significance of adaptive capacity, inclusive governance, and ethical considerations in navigating digital and environmental transitions. Ultimately, this book invites readers to rethink the meaning of development in the twenty-first century. It encourages a holistic perspective that recognizes the interdependence of digital innovation, economic systems, education, and the environment. By fostering dialogue across disciplines and sectors, this volume aims to contribute to the ongoing discourse on how societies can move toward development pathways that are not only technologically advanced, but also resilient, equitable, and sustainable for present and future generations.

Table of Contents

	Page
Preface	2
Prologue	3
Table of Content	5
 Environment	 10
101 COASTAL RECLAMATION AND SUSTAINABLE TOURISM: A LITERATURE REVIEW THROUGH THE VICE MODEL PERSPECTIVE <i>Ridha Khairunnisa Basso, Aras Mulyadi, and Eni Sumiarsih</i>	11
102 THE RELATIONSHIP BETWEEN ORGANIZATIONAL COMMITMENT AND ENVIRONMENTAL LEADERSHIP WITH COMMUNITY SATISFACTION FOR SUSTAINABLE ECOTOURISM DEVELOPMENT <i>Citra Sherly Gita, Ahman Sya, and Ananto Kusuma Seta</i>	16
103 THE ROLE OF MANGROVES IN BIODIVERSITY AND ECOSYSTEMS: OPPORTUNITIES FOR HUMAN ECOLOGICAL USE <i>Ahmad Faqih, Dewi Wahyuni K. Baderan, Nurdin, and Marini Susanti Hamidun</i>	21
104 YELLOW BAMBOO'S ROLE IN DISASTER MITIGATION AND SOCIO- ENVIRONMENTAL DYNAMICS IN BIYONGA- BULOTA <i>Ardiyanto S. Modjo, Mahludin H. Baruadi, Sukirman Rahim, Dewi W. K. Baderan</i>	26
105 SUSTAINABLE CARBON MANAGEMENT IN PRIMARY ENERGY OF COAL, OIL, AND RENEWABLE ENERGY <i>Yanto Sidik Pratiknyo, Wilson Bangun, Zainur Hidayah, Roni Kambara</i>	29
106 ENVIRONMENTAL MANAGEMENT STRATEGIES IN THE TRANSITION TO LOW- CARBON SMART CITIES: CHALLENGES AND OPPORTUNITIES <i>Ardiyanti, Desy Safitri, and Agung Purwanto</i>	35

		Page
107	RIVERBANKS AS GREEN INFRASTRUCTURE IN URBAN AREAS <i>Nurlita Pertiwi</i>	40
108	ANALYZING KUMPARAN GREEN INITIATIVE: A MODEL OF DIGITAL ENVIRONMENTAL JOURNALISM <i>Muhammad Darisman, Nadiroh, and Ananto Kusuma Seta</i>	45
109	INNOVATIONS IN WASTE MANAGEMENT TOWARD A GREEN OFFICE AT THE JAKARTA PRESIDENTIAL PALACE <i>Y. Astuti, A. Husen, and G. D. Artanti</i>	49
110	BUILDING COMMUNITY RESILIENCE VIA SOCIAL ECOLOGY IN SUSTAINABLE EDUCATION TO SUPPORT THE SUSTAINABLE DEVELOPMENT GOALS <i>Rihlah Nur Aulia and Anneke Stamer</i>	53
111	APPLICATION OF INPUT-OUTPUT LEONTIEF ANALYSIS FOR WATER TARIFF CALCULATION IN INTEGRATED WATER CYCLE MANAGEMENT <i>Martin Darmasetiawan and Teddy Tedjakusuma</i>	58
112	THE USE OF NAPIER GRASS (PENNISSETUM PURPUREUM cv. MOTT) FOR RIVERBANK PROTECTION <i>Asnita Virlayani, Nurlita Pertiwi, and Mithen Lullulangi</i>	64
113	INTEGRATED ENVIRONMENTAL MANAGEMENT FRAMEWORK FOR HOUSEHOLD WASTE IN RESILIENT, INCLUSIVE, AND LOW-CARBON SMART CITIES <i>Akhmad Qosasih, Ahman Sya, and Nadiroh</i>	69
114	URBAN FARMING AS A PATHWAY TO STRENGTHEN COMMUNITY ADAPTIVE CAPACITY TO CLIMATE CHANGE: OPPORTUNITIES AND CHALLENGES FROM MAKASSAR CITY <i>Moh. Ahsan S Mandra, Abdul Gafur, and Eka Apriyanti</i>	74
115	EVALUATION OF PHARMACEUTICAL WASTEWATER MANAGEMENT AND HORMONAL IMPACT ON GROUND WATER POLLUTION IN CIRACAS, EAST JAKARTA <i>Hasnah Lidiawati, Eliana Sari, and Muhammad Zid</i>	79

		Page
116	IMPACT OF INDUSTRY, TRAFFIC CONGESTION, AND GREEN OPEN SPACES ON TROPOSPHERIC OZONE CONCENTRATIONS <i>Robert Kurniawan, Agung Purwanto, and Bagus Sumargo</i>	84
117	ANALYSIS OF PHYSICAL WORK ENVIRONMENT IN NICKEL MINING INDUSTRY: A CASE STUDY OF PT X <i>Nurcitra Rehulina Br Ginting, I Made Astra, and Dwi Atmanto</i>	89
118	MOVING BED BIOFILM REACTOR (MBBR) AS AN ADVANCED BIOLOGICAL TECHNOLOGY FOR SUSTAINABLE WASTEWATER TREATMENT <i>Bheni David, Cahyadi Setiawan, and Dwi Atmanto</i>	94
119	SYSTEM DYNAMICS MODELLING OF PUBLIC TRANSPORTATION AND ENERGY TRANSITION IN JAKARTA'S SMART CITY DEVELOPMENT <i>Danang Pratomo, Eliana Sari, Bagus Sumargo, and Nadiroh Azizah</i>	98
120	LITERATURE STUDY ON THE ROLE OF EDUCATION AND PUBLIC PARTICIPATION IN MARINE PLASTIC POLLUTION REDUCTION <i>Nida' Farah Abiyya, Diana Vivianti, Samadi, Eliana Sari, and Dian A. Purwandari</i>	102
	Economic	106
201	OPTIMIZING MANGROVE CARBON STOCKS TO ACHIEVE INDONESIA'S FOLU NET SINK 2030 TARGET: ENVIRONMENTAL ENGINEERING SCIENCE PERSPECTIVE <i>Faisal M Jasin</i>	107
202	INTEGRATION OF ENVIRONMENTAL MANAGEMENT AND GREEN ECONOMY: A CASE STUDY OF KAMPUNG LABIRIN BOGOR <i>Arradina Zessa Devy, Yusup Ajang Setiadi, and Arief Aditya Hutama</i>	113

		Page
203	INTEGRATING FOESG DIMENSIONS FOR SUSTAINABLE STRATEGIC PERFORMANCE IN THE SUGAR INDUSTRY <i>Luthfi Jusniar Dwiputri, Eliana Sari, and Dian Alfia Purwandari</i>	118
	Education	123
301	EMPOWERING SMART STUDENTS THROUGH DIGITAL PROJECT-BASED LEARNING: TRANSFORMING CRAFT EDUCATION FOR SUSTAINABLE CITIES <i>Karimulloh*, Khaerudin, and Eveline Siregar</i>	124
302	EDUCATIONAL NONPROFIT LEADERSHIP AND DIGITAL TRANSFORMATION OF DEPOK CITY LIBRARY TOWARDS SMART SUSTAINABLE CITIES <i>Khairunnisa Putri Alif, Eliana Sari, and Neti Karnati</i>	128
303	THE INFLUENCE OF SOCIO-DEMOGRAPHIC CHARACTERISTICS ON STUDENTS' ENVIRONMENTAL CONCERN IN JAKARTA <i>Andrea Vondra, Sisean Baga, Robert Kurniawan, and Fidelia Fedoral</i>	134
304	INTEGRATING FLOOD PREPAREDNESS AND ECOLOGICAL CITIZENSHIP IN PRIMARY EDUCATION: EVIDENCE FROM EAST KALIMANTAN, INDONESIA <i>Arum Sekar Kedhaton and Prince Clinton Immanuel Christian Damanik</i>	139
305	DEEP LEARNING AND DIGITAL CITIZENSHIP FOR GREEN AND SUSTAINABLE EDUCATION: INSIGHTS FROM INDONESIA <i>Prince Clinton Immanuel Christian Damanik, and Arum Sekar Kedhaton</i>	144
306	DIGITAL TRANSFORMATION OF ISLAMIC RELIGIOUS EDUCATION: SHAPING “SMART PEOPLE” BASED ON ECOTHEOLOGY TOWARD A SMART AND SUSTAINABLE CITY <i>Zulfatun Ni'mah</i>	149

		Page
307	BUILDING STRONG CITIES THROUGH GREEN EDUCATION AND GOOD EDUCATIONAL MANAGEMENT <i>Sarah Muthmainnah</i>	154
308	PREPARING NEXT-GENERATION EDUCATIONAL LEADERS FOR ENVIRONMENTAL SUSTAINABILITY: LEADERSHIP TRENDS IN THE ERA OF CLIMATE- CONSCIOUS GENERATIONS <i>Lina and Rheza Pratama</i>	158
309	DIGITAL EDUCATION, ISLAMIC ETHICS, AND SMART CITIES: A HADITH- BASED PERSPECTIVE <i>Khairil Ikhsan Siregar, Muhammad Alif, and Izzatul Mardhiah</i>	164
310	MANAGING SCHOOL RESOURCES: A RESPONSIVE STRATEGY TOWARDS THE GO GREEN PROGRAMME R. Madhakomala and Sisca Cletus Lamatokan	169
	Humanities and Social Sciences	174
401	GREEN DIGITAL MARKETING: SEBUMI'S INNOVATION TO STRENGTHENING SUSTAINABLE TOURISM AMONG URBAN COMMUNITIES <i>Mega Ayu Permatasari, Noprita Herari, and Sandy Alifiansyah</i>	175
402	DIGITAL HUMAN RESOURCE DEVELOPMENT FOR SUSTAINABLE COMMUNITY COFFEE FARM TOURISM: AN ADDIE APPROACH FOR SMALLHOLDER COFFEE FARMS <i>Roni Faslah, Ervina Maulida, Puji Wahono, and Muhammad Ikhwan</i>	180
		Page
	Technology	185
501	ANALYSIS OF THE ROLE OF SMART HOMES IN ACHIEVING NET-ZERO CARBON TARGETS IN RESIDENTIAL BUILDINGS <i>Fani Akmalayah Safitri, Achmad Husen, Samadi, and Eliana Sari</i>	186

ENVIRONMENT

Scope : Environment
Article ID : 101

COASTAL RECLAMATION AND SUSTAINABLE TOURISM: A LITERATURE REVIEW THROUGH THE VICE MODEL PERSPECTIVE

Ridha Khairunnisa Basso*, Aras Mulyadi, and Eni Sumiarsih

Master of Environmental Science, Postgraduate Program, Universitas Riau, Indonesia

Email: *aras.mulyadi@lecturer.unri.ac.id

Abstract

Coastal reclamation has become a global phenomenon that increasingly affects the sustainability of coastal tourism. This study aims to review recent literature on the impacts of reclamation on sustainable tourism, with particular emphasis on environmental, social, economic, and governance aspects. A qualitative descriptive approach was applied through a literature review of scientific articles, policy reports, and related documents published between 2021 and 2025. The findings indicate that reclamation generates ecological pressures, alters community livelihoods, and influences tourism attractiveness, while governance frameworks often remain weak. However, there is a limited number of studies that integrate reclamation issues within the Visitor, Industry, Community, and Environment (VICE) Model. This review highlights the need for a more comprehensive theoretical framework to design strategies for sustainable coastal tourism management.

Keywords: Reclamation, Sustainable Tourism, VICE Model, Coastal Area

Introduction

Coastal reclamation has become a widespread development approach with far-reaching implications for environmental, social, and economic systems. While reclamation projects aim to expand land for infrastructure and tourism, they often generate serious ecological degradation, biodiversity loss, and declining water quality (Lahutung et al., 2025; Pratama et al., 2025). In the context of climate change and sea-level rise, reclamation further intensifies coastal vulnerability, requiring a governance framework grounded in sustainability.

In Indonesia, reclamation has been implemented across urban and tourism coastal zones. As a maritime nation, Indonesia faces the dual challenge of promoting economic growth through reclamation while maintaining environmental and social integrity (Pratama et al., 2024; Wattimena & Leatemia, 2024). Examples from Jakarta Bay, Makassar, and Semarang show that reclamation often triggers ecological and social conflicts due to weak governance and limited community participation (Puspasari et al., 2017; Sastia et al., 2024). These cases highlight the urgency of integrating sustainability principles into coastal policy.

Tourism, as one of the sectors most directly affected by reclamation, plays a strategic role in sustainable development. Beyond its economic contribution, tourism supports cultural preservation and regional branding. However, reclamation that disregards environmental carrying capacity can diminish the attractiveness of coastal destinations and reduce long-term competitiveness (Purba & Surbakti, 2021). The case of Dumai, Riau Province, exemplifies this

dilemma. Reclamation activities in Koneng Beach, a local coastal tourism site, have sparked ecological, social, and legal concerns, including permit violations reported by the Ministry of Marine Affairs and Fisheries (Harahap, 2023; Listiyarini & Tanudjaja, 2025). This situation underscores the complexity of aligning reclamation practices with sustainable tourism objectives. Despite increasing research on reclamation, few studies analyze its relationship with tourism sustainability comprehensively. The Visitor, Industry, Community, and Environment (VICE) Model offers a multidimensional approach for assessing tourism impacts (Abdul et al., 2016; Schumann, 2021). This paper reviews recent literature (2021–2025) to identify reclamation's environmental, social, and economic impacts and explores how the VICE Model can guide sustainable coastal tourism management.

Method

This study adopts a qualitative descriptive method through a literature review. Data were obtained from scientific journals, policy reports, and institutional documents published between 2021 and 2025. Sources were selected based on relevance and credibility. Thematic analysis was used to identify trends and challenges in reclamation-related studies, with findings categorized according to the four dimensions of the VICE Model: Visitor, Industry, Community, and Environment.

Result and Discussion

The review of recent literature (2021–2025) shows that coastal reclamation has far-reaching consequences for sustainable tourism. These consequences are best explained through the VICE Model, which integrates Visitor, Industry, Community, and Environment dimensions (Abdul *et al.*, 2016; Schumann, 2021).

1. Visitor Dimension

Reclamation modifies natural landscapes, affecting tourist satisfaction and perception. Research in Jakarta Bay, Losari Makassar, and Dumai indicates that while infrastructure may improve, loss of coastal authenticity reduces visitor appeal (Harahap, 2023; Pratama et al., 2024). Tourists increasingly value ecological quality and cultural integrity; thus, environmental degradation diminishes destination competitiveness (Chee et al., 2023; Li et al., 2023).

2. Industry Dimension

Reclamation creates opportunities for large-scale tourism and real estate projects but marginalizes small enterprises and traditional livelihoods (Wattimena & Leatemia, 2024). In many cases, industrial activities dominate reclaimed zones, reducing inclusive tourism growth (Puspasari et al., 2017). Strengthening local business participation and equitable land-use planning is vital for sustainable industry resilience (Blancas et al., 2023).

3. Community Dimension

Local communities often experience social and economic displacement. Reclamation disrupts fisheries, reduces coastal access, and limits involvement in decision-making (Lahutung et al., 2025; Listiyarini & Tanudjaja, 2025). In Dumai, conflicts arise when reclamation serves industrial rather than communal interests (Harahap, 2023). Sustainable tourism requires participatory governance that ensures community benefit-sharing (Jiang et al., 2024).

4. Environment Dimension

Ecological degradation remains the most immediate impact of reclamation. Studies report accelerated erosion, mangrove loss, and declining water quality in many Indonesian coasts (Puspasari et al., 2017; Sastia et al., 2024). At Koneng Beach, unlicensed activities intensified environmental risks (Listiyarini & Tanudjaja, 2025). These impacts reduce ecological carrying capacity and resilience against climate hazards (Lu et al., 2023; Sengupta et al., 2023).

Despite abundant studies, most remain fragmented. Environmental and legal aspects dominate the discourse, while the Visitor and Industry dimensions are rarely addressed. More importantly, no study systematically applies the VICE Model to analyze reclamation's implications for sustainable tourism. This study contributes novelty by employing the VICE Model as a holistic framework, bridging environmental, social, and economic dimensions to design sustainable coastal tourism strategies (Crabolu *et al.*, 2024; Miller & Torres-Delgado, 2023).

Table 1. Literature Synthesis on Coastal Reclamation and Tourism (2021–2025)

Author(s), year	Case/Focus	Main Findings	Limitation (VICE Perspective)
Pratama <i>et al.</i> , 2024	Marina beach landform	Ecological degradation, reduced tourism appeal	Visitor & industry impacts not assessed
Sastia <i>et al.</i> , 2024	Losari reclamation (Makassar)	Environmental loss, urban expansion	Focused only on environment
Harahap 2023	Dumai coastal reclamation	Abrasion impacts, declining livelihoods	No link to industry competitiveness
Lahutung <i>et al.</i> , 2025	Legal aspects of reclamation	Weak governance, policy inconsistency	Did not integrate tourism sustainability
Wattimena & Leatemia., 2024	Coastal ecosystems	Industrial expansion harming ecology	Ignored visitor & community aspects
Listiyarini & Tanudjaja., 2025	Legal certainty	Permit violations highlighted	No analysis of tourism outcomes
Purba & Surbakti., 2021	Koneng beach potential	Conservation-based tourism opportunities	Did not assess reclamation threats

As summarized in Table 1, most studies emphasize environmental or legal impacts of reclamation. Social and economic issues are less addressed, and tourism-focused dimensions remain marginal. Importantly, none employ the VICE Model comprehensively. This confirms a research gap in multidimensional assessments, which this review addresses by highlighting the VICE framework as an innovative tool for analyzing reclamation and sustainable tourism.

Conclusion

This study concludes that coastal reclamation has a significant impact on the sustainability of tourism at Koneng Beach, Dumai. By applying the VICE Model, the research demonstrates that reclamation influences not only the ecological quality of the coastal environment but also the dynamics of visitors, the competitiveness of the tourism industry, and the livelihoods of local communities. The analysis confirms that reclamation tends to prioritize industrial expansion, while ecological resilience and community inclusiveness remain neglected.

The novelty of this study lies in the comprehensive use of the VICE Model to evaluate reclamation impacts on sustainable tourism. This approach provides a holistic perspective that bridges environmental, social, and economic dimensions, thereby offering a new framework for assessing and managing coastal reclamation projects in Indonesia.

Future research is recommended to explore quantitative models for measuring the intensity of reclamation impacts, as well as to develop adaptive strategies for balancing ecological restoration, industrial growth, and community-based tourism development.

Acknowledgment

The author would like to express sincere gratitude to Universitas Riau, particularly the Master of Environmental Science Program, for the academic guidance and support during the completion of this research. Appreciation is also extended to the Dumai City Tourism Office and the local community of Medang Kampai District for their valuable assistance in providing data and field information. Special thanks are conveyed to the reviewers of the 1st International Conference on Environment, Education, Social Science, and Humanities (ICE3SHT 2025) for their constructive feedback that helped improve the quality of this manuscript.

References

- Abdul, A., Abdul, R., & Mugod. (2016). Sustainable Tourism Planning by using the VICE Model (Applied on Minia Governorate). *Minia Journal of Tourism Hospitality Research*, 1(2), 98–113.
- Blancas, F. J., Contreras, I., & Lozano-Oyola, M. (2023). Evaluating destinations' efforts to improve sustainability in tourism using the inter-temporal decomposition of a composite indicator. *Environmental Impact Assessment Review*, 98(September 2022), 106947. <https://doi.org/10.1016/j.eiar.2022.106947>
- Chee, S. Y., Tan, M. L., Tew, Y. L., Sim, Y. K., Yee, J. C., & Chong, A. K. M. (2023). Between the devil and the deep blue sea: Trends, drivers, and impacts of coastal reclamation in Malaysia and way forward. *Science of The Total Environment*, 858, 159889. <https://doi.org/10.1016/J.SCITOTENV.2022.159889>
- Crabolu, G., Font, X., & Miller, G. (2024). The Hidden Power of Sustainable Tourism Indicator Schemes: Have We Been Measuring Their Effectiveness All Wrong? *Journal of Travel Research*, 63(7), 1741–1760. <https://doi.org/10.1177/00472875231195736>
- Harahap, A. R. (2023). *Impact of Abrasion on Coastal Ecotourism Area in Medang Kampai District, Dumai City, Riau Province*. 28(3), 372–380.
- Jiang, X., Liu, F., Yu, J., Zhang, K., Zhang, Z., & Wang, Q. (2024). Global Trends and Prospects of Community Participation in Marine Protected Areas: A Bibliometric Analysis. *Sustainability*, 16(17), 1–19. <https://doi.org/10.3390/su16177772>
- Lahutung, R. J., Bawole, H. Y. A., & Tinangon, E. N. (2025). Analisis Hukum Dampak Reklamasi Pantai terhadap Ekosistem Laut di Kabupaten Kepulauan Siau Tagulandang Biaro. *LEX ADMINISTRATUM*, 13(1).
- Li, J., Leng, Z., Yuguda, T. K., Wei, L., Xia, J., Zhuo, C., Nie, Z., & Du, D. (2023). Increasing coastal reclamation by Invasive alien plants and coastal armoring threatens the ecological sustainability of coastal wetlands. *Frontiers in Marine Science*, 10(February), 1–15. <https://doi.org/10.3389/fmars.2023.1118894>
- Listiyarini, R., & Tanudjaja. (2025). Kepastian Hukum Penyelenggaraan Reklamasi Dengan Perundang Undangan Ruang Laut Di Wilayah Pesisir Indonesia. *PESHUM: Jurnal Pendidikan, Sosial dan Humaniora*, 4(3), 3895–3900. <https://doi.org/10.57096/lentera.v3i2.147>
- Lu, J., Lv, X., & Shi, H. (2023). Spatio-Temporal Heterogeneity and Cumulative Ecological Impacts of Coastal Reclamation in Coastal Waters. *Remote Sensing*, 15(6). <https://doi.org/10.3390/rs15061495>
- Miller, G., & Torres-Delgado, A. (2023). Measuring sustainable tourism: a state of the art review of sustainable tourism indicators. *Journal of Sustainable Tourism*, 31(7), 1483–1496. <https://doi.org/10.1080/09669582.2023.2213859>
- Pratama, J. P., Rohmansyah, R., Puntodewo, L., & Rahman, F. A. (2025). Ketahanan Masyarakat Pesisir terhadap Dampak Perubahan Iklim (Studi Kasus Nelayan dan Pelaku Usaha di Kecamatan Paku Haji). *Journal of Management and Social Sciences*, 4(1), 20–36.
- Pratama, M. T., Fajri, F. Q., Salwa, A., & Wulanuari, A. (2024). Analisis Dampak Perubahan Bentuk Lahan Pantai Marina Sebelum Dan Sesudah Reklamasi. *Jurnal Implementasi*, 4(1), 55–64.

Purba, M. A., & Surbakti, R. (2021). Potensi Pengembangan Wisata Lokal Pantai Pasir Koneng untuk Pelestarian di Kecamatan Medang Kampai, Kota Dumai, Provinsi Riau. *Prosiding Seminar Nasional Peningkatan Mutu Pendidikan*, 2(1), 165–168.

Puspasari, R., Hartati, S. T., & Anggawangsa, R. F. (2017). Analisis Dampak Reklamasi Terhadap Lingkungan dan Perikanan di Teluk Jakarta. *Jurnal Kebijakan Perikanan Indonesia*, 9(2), 85–94.

Sastia, N. T., Mawarni, I. S., & Ahmad, R. S. (2024). Dampak Reklamasi Pantai Losari Menjadi Kawasan Central Point of Indonesia (Cpi). *Jurnal Ilmiah Kajian Multidisipliner*, 8(6), 2118–7302.

Schumann, F. (2021). Monitoring changes in resident attitudes toward tourism development in small island destinations : What comes next in a post-COVID world ? Monitoring changes in resident attitudes toward tourism development in small island destinations : What comes next i. *Journal of Global Tourism Research*, 6(1), 61–66. <https://doi.org/10.37020/jgtr.6.1>

Sengupta, D., Choi, Y. R., Tian, B., Brown, S., Meadows, M., Hackney, C. R., Banerjee, A., Li, Y., Chen, R., & Zhou, Y. (2023). Mapping 21st Century Global Coastal Land Reclamation. *Advancing Earth and Space Science*, 11(2), 1–13. <https://doi.org/10.1029/2022EF002927>

Wattimena, J. A. Y., & Leatemia, W. (2024). Kerusakan Ekosistem Pesisir: Reklamasi Wilayah Jawabannya? *Uti Possidetis: Journal of International Law*, 5(1), 138–154.

Scope : Environment

Article ID : 102

THE RELATIONSHIP BETWEEN ORGANIZATIONAL COMMITMENT AND ENVIRONMENTAL LEADERSHIP WITH COMMUNITY SATISFACTION FOR SUSTAINABLE ECOTOURISM DEVELOPMENT

Citra Sherly Gita*, Ahman Sya, and Ananto Kusuma Seta

Master of Enviromental Management, Post Graduate School, Jakarta State University, Indonesia

E-mail: *Citrasherlygita_9914821001@mhs.unj.ac.id

Abstract

This examination examines the relationship between organizational dedication and environmental leadership with community pride in the development of sustainable ecotourism at Lake Sipin, Jambi city. The studies heritage emphasizes the significance of community participation and organizational support to ensure the achievement of ecotourism management that enhances neighborhood welfare at the same time as keeping the surroundings. A quantitative technique with a case look at layout was hired, concerning applicable agencies and nearby communities around Lake Sipin. Sampling techniques covered multistage purposive sampling and easy random sampling, with statistics amassed through questionnaires, interviews, and documentation. A couple of linear regression evaluations have been implemented to systemize the facts. The findings are expected to offer theoretical contributions regarding elements influencing network pride and serve as sensible references for neighborhood governments and stakeholders in formulating techniques for sustainable ecotourism development.

Keywords: organizational commitment; environmental leadership; community pleasure; sustainable ecotourism

Introduction

Ecotourism and mass tourism possess distinct traits. Ecotourism is regarded as a form of sustainable tourism development that emphasizes environmental conservation, community well-being, and educational advancement. In contrast, the extra traditional form of tourism development, which tends to focus on brief-time period profits, is recognized as mass tourism. The improvement of ecotourism is predicted to minimize terrible effects on ecosystems and the environment via accountable and sustainable management practices. moreover, ecotourism is anticipated to generate nice economic contributions for nearby groups through empowerment applications and the creation of sustainable tourism companies. It additionally pursuits to admire and maintain local tradition by way of imparting possibilities for communities to hold and expand their cultural history.

The development technique of ecotourism need to be participatory, related to all stakeholders to make sure shared obligation and inclusiveness. The Province of Jambi has experienced a vast increase in the tourism area, with numerous of its destinations gaining international reputation. Jambi has correctly enhanced its tourism capability through the development of various natural and cultural attractions, supported by effective management from each the government and nearby groups.

The establishment of ecotourism at Lake Sipin is predicted to foster nice public perceptions of the lake's capacity as a tourism destination that may enhance the welfare of surrounding communities. community projects to make use of the lake as a tourism asset that blessings each the local economic system and the environment also are expected to emerge. But, the sustainable development of ecotourism in Lake Sipin cannot be completed without the lively participation and robust help of nearby citizens in Jambi metropolis

Method

The study's loction refers back to the website where the have a look at is carried out to attain answers or answers to the studies issues. In accordance with the studies identify, the chosen research websites include the Environmental Business enterprise (Dinas Lingkungan Hidup), the local development making plans organization (Badan Perencanaan Daerah). The general public Works Departement (Dinas Pekerjaan Umum), and the groups libing in Sungai Putri and Legok Sub-districts, Danau Sipin District, Jambi metropolis. These location were selected due to fact that they are located near the Lake Sipin ecotourism place, Where numerous Tourism recognition corporations (Kelompok Sadar Wisata/POKDARWIS) are actibely engaged in tourism-related activities, which include boat services, water cyling, and local culinary businesses. Furthermore, to reap samples from peronnell of ecotourism control groups and assocoied organizations, a purposive sampling approach became employed. This approach involved deciding on individuals who are immediately involved in selection-making and the implementation of ecotourism improvement packages.

Result and Discussion

The remark of the ecotourism place around Lake Sipin presents a realistic evaluation of the modern-day situation of tourism management and community participation. The findings from field documentation show that the physical environment and supporting infrastructure still require development to achieve sustainable ecotourism standards. Similar findings were emphasized by Bhuiyan, Siwar, and Ismail (2017), who stated that inadequate infrastructure and poor environmental management remain major challenges for achieving sustainability in Southeast Asian ecotourism sites.

The first remark suggests that several public facilities, including trash bins and parking areas, are poorly maintained, suggesting limited environmental control and low community awareness of cleanliness. This situation reflects the level of organizational commitment to maintaining environmental quality, which directly influences community satisfaction. According to Elshaer and Marzouk (2019), high organizational commitment within tourism management institutions significantly improves service delivery and community perception of sustainability. A lack of coordinated efforts between local government agencies and tourism organizations may result in public dissatisfaction, as environmental cleanliness is a fundamental component of sustainable tourism (Rahman & Alam, 2020).

The second remark highlights the condition of several public buildings and service facilities near the tourism area, which appear neglected and in need of renovation. This finding underscores the importance of environmental leadership, particularly in fostering shared responsibility among stakeholders. Leaders who demonstrate environmental awareness and provide clear direction to both government officials and community members can strengthen commitment to sustainability (Ahmad & Usop, 2020; Northouse, 2021). Leadership plays a crucial role in ensuring that tourism development not only focuses on financial outcomes but also upholds social and ecological values. As Han and Hyun (2017) pointed out, environmental leadership enhances public satisfaction by integrating environmental consciousness into organizational goals and tourism practices.

The third and fourth observations showing parking facilities and the lake area illustrate that Lake Sipin possesses significant potential for tourism attraction but still faces environmental management challenges. The existence of informal vendors and small-scale tourism activities indicates community involvement; however, without clear regulation and environmental education, these activities risk degrading the ecosystem. Strengthening organizational commitment through structured programs and transparent communication can enhance coordination among agencies, the private sector, and local residents. This aligns with Bramwell and Lane (2015), who highlighted the importance of governance and multi-stakeholder collaboration for sustainable tourism development.

The fifth and sixth observations show lake access areas used for boat tourism and recreational activities. However, waste accumulation along the shoreline indicates the absence of consistent waste management practices. This issue shows that community satisfaction depends not only on the availability of tourism activities but also on environmental quality and comfort. The principle of responsible environmental leadership involving planning, supervision, and evaluation is essential to ensure that ecotourism practices remain sustainable and beneficial for all stakeholders (Dangi & Jamal, 2016; Ghorbani & Raufirad, 2020). Similarly, Alsubaie and Al-Sulami (2023) emphasized that environmental cleanliness is a key determinant of community satisfaction in ecotourism destinations.

The final observation, depicting food stalls and gathering spots along the lake, demonstrates strong social interaction and economic opportunities for local residents. This suggests that community participation is relatively high, although it still requires institutional guidance. Enhancing organizational commitment through collaborative management between the government, local tourism organizations (POKDARWIS), and residents can improve service quality and visitor satisfaction. This is consistent with the studies of Sugiarto and Wahyudi (2021) and Baniya and Paudel (2022), which concluded that active community involvement combined with institutional support is essential for sustainable ecotourism success.

Overall, the analysis indicates that organizational commitment and environmental leadership are interrelated factors that shape community satisfaction. High organizational commitment ensures that policies and programs are consistently implemented, while environmental leadership provides direction and motivation for community engagement. Both elements support the creation of sustainable ecotourism, where environmental preservation, cultural respect, and economic growth coexist harmoniously. This conclusion aligns with the broader framework proposed by UNEP and UNWTO (2018), which emphasizes that sustainable tourism must integrate environmental, social, and economic dimensions through participatory governance.

These findings emphasize that achieving sustainable ecotourism at Lake Sipin requires not only infrastructural improvement but also the strengthening of institutional capacity and leadership commitment at all levels. Empowering local communities, improving coordination among government agencies, and promoting environmentally responsible leadership are key strategies to enhance community satisfaction and realize the vision of sustainable tourism in Jambi City. As highlighted by the World Tourism Organization (UNWTO, 2023), inclusive leadership, strong institutional commitment, and community empowerment are the foundations for achieving long-term sustainability in ecotourism destinations.

Conclusion

The observe on the connection between organizational commitment and environmental management with community pleasure in the development of sustainable ecotourism at Lake Sipin reveals that both elements play an essential position in ensuring a hit and sustainable tourism management. The observations display that the contemporary situation of the ecotourism place

nonetheless faces challenges in environmental cleanliness, infrastructure upkeep, and network participation. However, these situations additionally indicate strong potential for development through coordinated moves and powerful leadership.

Organizational dedication, particularly from authorities' organizations and tourism-associated establishments, influences the consistency and high-quality of ecotourism control. When organizational commitment is strong, rules and programs geared toward sustainability may be carried out more successfully, ensuing in advanced environmental great and public consider.

Likewise, environmental leadership contributes substantially to shaping responsible attitudes and behaviors among stakeholders. Leaders who are environmentally aware can inspire communities to actively participate in conservation and to align monetary pursuits with sustainable standards. Network delight, as reflected within the social and monetary engagement of nearby citizens, is a key indicator of sustainable ecotourism success. The participation of local communities round Lake Sipin through tourism awareness businesses, small agencies, and environmental tasks demonstrates their willingness to guide ecotourism improvement. However, sustainable effects will simplest be carried out if community involvement is guided by clean organizational regulations and strong environmental management.

In conclusion, the improvement of sustainable ecotourism in Lake Sipin requires an integrated technique that strengthens organizational dedication, promotes environmental management, and enhances network satisfaction. Collaborative control among neighborhood governments, tourism companies, and citizens needs to focus on preserving environmental high-quality, improving infrastructure, and empowering the network. These efforts will make sure that Lake Sipin evolves into a model of sustainable ecotourism that balances ecological renovation, cultural values, and neighborhood economic growth.

Acknowledgment

The writer would like to express honest gratitude to all parties who have supplied help at some stage in the completion of this study. Special appreciation is extended to the academics and educational supervisors at the State University of Jakarta (Universitas Negeri Jakarta) for his or her treasured guidance, optimistic comments, and non-stop encouragement at some stage in the preparation of this thesis and research method.

The writer also wishes to thank all colleagues and team of workers contributors from the Environmental organisation, regional improvement planning organisation, and Public Works branch of Jambi city for their cooperation and assistance at some point of records collection.

Private appreciation is also conveyed to the writer's own family for his or her infinite love, persistence, and unwavering moral support, which became the greatest motivation to complete this examination eventually. A sincere thank you is addressed to all individuals and groups involved in the development of Lake Sipin Ecotourism, whose participation and insights contributed significantly to the fulfillment of this study.

References

- Ahmad, S., & Usop, A. M. (2020). Leadership and sustainable tourism development: A framework for community-based ecotourism. *Sustainability*, 12(18), 7634. <https://doi.org/10.3390/su12187634>
- Alsubaie, A. M., & Al-Sulami, Z. (2023). Community engagement and satisfaction in sustainable tourism destinations: Evidence from coastal ecotourism. *Sustainability*, 15(4), 3471. <https://doi.org/10.3390/su15043471>
- Ariffin, A. A., & Yahaya, A. (2018). Organizational commitment and its relationship with employee performance in tourism institutions. *International Journal of Academic Research in Business and Social Sciences*, 8(12), 654–667.

- Baniya, R., & Paudel, K. (2022). Exploring the relationship between leadership styles and community satisfaction in ecotourism. *Journal of Tourism and Development*, 46(2), 93–107.
- Bhuiyan, M. A. H., Siwar, C., & Ismail, S. M. (2017). Ecotourism and environmental sustainability: An empirical study in Malaysia. *Sustainability*, 9(1), 47. <https://doi.org/10.3390/su9010047>
- Bramwell, B., & Lane, B. (2015). Critical research on the governance of tourism and sustainability. *Journal of Sustainable Tourism*, 23(1), 1–8. <https://doi.org/10.1080/09669582.2014.977751>
- Choi, H. C., & Sirakaya, E. (2016). Sustainability indicators for managing community tourism. *Tourism Management*, 27(6), 1274–1289. <https://doi.org/10.1016/j.tourman.2005.05.018>
- Dangi, T. B., & Jamal, T. (2016). An integrated approach to “sustainable community-based tourism.” *Sustainability*, 8(5), 475. <https://doi.org/10.3390/su8050475>
- Elshaer, I. A., & Marzouk, A. (2019). Organizational commitment, job satisfaction, and performance in tourism organizations. *Tourism Management Perspectives*, 31, 257–267. <https://doi.org/10.1016/j.tmp.2019.05.008>
- Ghorbani, A., & Raufirad, V. (2020). Local community involvement in ecotourism and its contribution to sustainability: A case of Iran. *Journal of Outdoor Recreation and Tourism*, 31, 100326. <https://doi.org/10.1016/j.jort.2020.100326>
- Han, H., & Hyun, S. S. (2017). Drivers of customer satisfaction in sustainable tourism: Environmental values and leadership influence. *Journal of Travel & Tourism Marketing*, 34(5), 624–639. <https://doi.org/10.1080/10548408.2016.1208787>
- Lee, T. H. (2018). How attitude and behavior of local residents affect sustainable tourism. *Tourism Management*, 64, 355–366. <https://doi.org/10.1016/j.tourman.2017.09.013>
- Lu, J., & Nepal, S. K. (2019). Sustainable tourism research: An analysis of papers published in *Tourism Management*, 2000–2018. *Tourism Management*, 75, 245–259. <https://doi.org/10.1016/j.tourman.2019.05.020>
- Northouse, P. G. (2021). *Leadership: Theory and practice* (9th ed.). Sage Publications.
- Rahman, M. S., & Alam, M. (2020). The role of organizational commitment and leadership in sustainable tourism development. *Sustainability*, 12(14), 5702. <https://doi.org/10.3390/su12145702>
- Sugiarto, E., & Wahyudi, W. (2021). Community participation and local leadership in sustainable tourism development in Indonesia. *Jurnal Manajemen dan Kewirausahaan*, 23(1), 12–25. <https://doi.org/10.9744/jmk.23.1.12-25>
- Sutopo, A. H., & Slamet, R. (2022). The impact of leadership style and organizational commitment on employee performance in tourism services. *International Journal of Management Studies*, 9(4), 233–245.
- UNEP & UNWTO. (2018). *Tourism and the Sustainable Development Goals – Journey to 2030*. Madrid: World Tourism Organization.
- World Tourism Organization (UNWTO). (2023). *Ecotourism and community well-being: Global best practices*. Retrieved from <https://www.unwto.org>
- Yusof, M. N., & Jamaluddin, M. R. (2019). Assessing the community satisfaction in ecotourism development: Evidence from Southeast Asia. *Journal of Ecotourism*, 18(3), 205–220. <https://doi.org/10.1080/14724049.2018.1561412>

Scope : Environment

Article ID : 103

THE ROLE OF MANGROVES IN BIODIVERSITY AND ECOSYSTEMS: OPPORTUNITIES FOR HUMAN ECOLOGICAL USE

Ahmad Faqih*, Dewi Wahyuni K. Baderan, Nurdin, and Marini Susanti Hamidun

Environmental Science, Postgraduate, Gorontalo State University, Gorontalo, Indonesia

E-mail: [*ahmadfaqih377@gmail.com](mailto:ahmadfaqih377@gmail.com)

Abstract

Mangrove ecosystems are vital for maintaining biodiversity and ecosystem balance locally and globally. They provide habitats for diverse marine and terrestrial species and serve as buffers against natural disasters and climate change impacts. This study analyzes the role of mangroves in preserving biodiversity and explores their potential use in human ecology, focusing on Gorontalo Province, Indonesia. In Indonesia, mangroves face threats from land conversion for development, agriculture, and industry, yet they hold significant ecological value by offering vital services like erosion reduction, carbon absorption, and disaster protection. In Gorontalo, mangroves are a crucial natural resource that requires better management. This research identifies sustainable utilization opportunities, such as fisheries, ecotourism, and processed mangrove products. By involving local communities in conservation efforts, mangrove ecosystems can enhance the social and economic well-being of coastal populations while ensuring sustainability. The findings aim to inform more effective mangrove management policies in Indonesia.

Keywords: Mangrove Ecosystem; Biodiversity; Human Ecology

Introduction

Biodiversity threats, or ecological vulnerability, are evident in Indonesia's coastal and marine areas due to development and unsustainable fishing. One of the ecosystems most vulnerable to damage is the mangrove ecosystem, which is crucial for marine biodiversity and provides protection against natural disasters such as tsunamis and storm surges (Alongi, 2020). Mangroves provide sustainable opportunities for conservation, nature-based tourism, fisheries, and resource management.

Mangrove ecosystems play a crucial role in maintaining the balance of coastal environments and biodiversity (Maryani *et al.*, 2025). Mangroves provide various ecosystem services, including coastal protection from abrasion and erosion, carbon dioxide absorption, and habitat for a variety of marine and terrestrial species (Imburi *et al.*, 2024). Mangrove forests also support fishery production and provide resources for coastal communities, such as firewood, building materials, and medicinal plants (Fikri *et al.*, 2023). However, mangrove ecosystems face significant threats that lead to degradation and loss of their ecological functions (Al Idrus, 2018). A human ecology approach to natural resource use is vital for climate change and population growth. In mangrove ecosystems, restoration, ecotourism, and product processing offer ecological and economic benefits, while conservation areas help maintain biodiversity and support communities, especially in Indonesia (Kurniawansyah *et al.*, 2023).

In Indonesia, mangrove forests experience immense pressure from human activities, such as land conversion for development, agriculture, and shrimp farming (Imburi *et al.*, 2024). Deforestation of mangroves has resulted in the loss of critical habitats for various species,

increased coastal erosion, and decreased water quality. Additionally, pollution from industrial and domestic waste also contributes to the degradation of mangrove ecosystems (Saidah *et al.*, 2024). The destruction of mangroves can negatively impact coastal communities that rely on mangrove resources for their livelihoods and protection from natural disasters.

Conservation efforts and sustainable management of mangroves are essential for preserving biodiversity and the functions of mangrove ecosystems (Dewi *et al.*, 2022). Involving local communities in eco-tourism and mangrove rehabilitation can enhance socio-economic benefits while restoring degraded ecosystems through effective planning (Imburi *et al.*, 2024). With an integrated approach involving various stakeholders, mangrove ecosystems can continue to provide benefits for the environment and human well-being.

In Gorontalo Province, conservation areas preserve biodiversity and support local communities. Empowering locals through mangrove restoration, education, and ecotourism fosters sustainable livelihoods and beneficial human-nature relationships (Berkes, 2017). Thus, community-based management and wise utilization of natural resources can enhance the quality of life for communities while preserving nature.

Gorontalo has opportunities to develop conservation areas that protect ecosystems and empower local communities. Conservation-based tourism and community involvement in decision-making can raise biodiversity awareness and provide sustainable economic benefits, highlighting the need for holistic management policies involving all stakeholders.

Method

This research employs a literature study approach to collect, analyze, and interpret various relevant secondary sources, including scientific journals, articles, books, and reports, related to mangroves. The focus of the research is on the role of mangroves in maintaining biodiversity and ecosystems, as well as the opportunities for their utilization in supporting human ecology, particularly in terms of social, economic, and ecosystem sustainability.

Result and Discussion

1. Biodiversity, Ecosystems, and Their Vulnerabilities as well as Opportunities for Utilization in Human Ecology

Mangrove biodiversity encompasses the diverse array of organisms inhabiting mangrove ecosystems, including plants, animals, microorganisms, and the intricate ecological interactions among species within these ecosystems (Hardiansyah & Noorhidayati 2020). Mangrove ecosystems in tropical and subtropical regions are vital for ecological balance. Key species like *Rhizophora*, *Avicennia*, and *Bruguiera* adapt to extreme conditions and provide coastal protection and habitats for diverse fauna (Alongi, 2020). This aligns with research by Djamadi *et al.* (2024), which identified six species on the coast of Tabongo: *Sonneratia alba*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera gymnorrhiza*, and *Avicennia alba*.

Mangroves support diverse fauna, offering shelter and breeding grounds for fish like grouper and mullet, as well as crustaceans, which are vital for the ecosystem's nutrient cycle. Research conducted by Faqih and Juramang (2023) indicates that the crustacean diversity index in the coastal area of Langala shows moderate diversity with species including *Lethrinus mahsena*, *Uca forcipata*, *Epixantus dentatus*, *Parathelphusa convexa*, *Metacarcinus magister*, *Metapenaeus monoceros*, *Metapenaeus elegans*, and *Litopenaeus vannamei*. This diversity supports the ecological balance that affects water quality and the welfare of coastal communities dependent on mangrove natural resources (Kathiresan, 2018).

Mangrove biodiversity includes microorganisms like bacteria and algae, essential for decomposing organic matter, cycling nutrients, enhancing soil fertility, and purifying pollutants, thus improving water quality in mangrove ecosystems (Giri, 2023). Mangrove biodiversity faces threats from deforestation for coastal development, climate change, and rising sea levels.

Protecting and rehabilitating mangrove ecosystems is crucial for preserving their biodiversity (Mumby, 2017).

Conservation efforts for mangrove biodiversity include replanting, water quality monitoring, and sustainable management. Research on species diversity and interspecies interactions helps develop effective conservation policies and strategies. (Feller *et al.*, 2023).

2. Human Ecology in Conservation Areas

a. The Role of Conservation Areas

Mangrove conservation is vital for the socio-economic and cultural resilience of coastal communities. They provide essential services like food, fuel, and medicine. In Indonesia, the Bajo tribe integrates ecological interests into their practices, valuing traditions like *Mamia Kadialo*, which promote ecosystem preservation and sustainable fishing, demonstrating the importance of local knowledge alongside scientific advancements in maritime life (Utina, 2012). Local wisdom and knowledge of the Bajo community embody ecological values. Delving into this can adapt practices for other coastal communities and provide constructive input for coastal management policies (Utina, 2014).

The Tanjung Panjang Nature Reserve in Pohuwato, Gorontalo, is a vital conservation area with rich biodiversity, including mangroves. However, land conversion for shrimp and fish ponds has reduced mangrove forests from 3,000 to 400 hectares, threatening wildlife habitats and essential ecosystem services (Mongabay, 2019). Mangrove conservation mitigates climate change, protects against disasters, and supports coastal ecosystem sustainability.

b. Conflicts and Cooperation: Involvement of Local Communities, Education, and Awareness

Conflicts in mangrove conservation arise from local practices harming ecosystems, like land conversion. However, participatory approaches involving communities in all management stages can minimize these conflicts and enhance environmental awareness. Education and environmental awareness are vital in resolving conflicts. Engaging e-modules with illustrations and case studies can enhance students' understanding of mangrove conservation and foster ecological awareness in the younger generation. (Kurniadini & Putra, 2024). Cooperation among government, communities, and NGOs is essential for mangrove conservation. Effective communication enhances awareness, supports local economies, and fosters sustainable mangrove ecotourism. (Islamia & Purwanto, 2025).

Mangrove ecotourism can reduce conflicts and enhance cooperation. Education-based tourism raises awareness about mangrove ecosystems and conservation efforts, encouraging active community participation in preservation initiatives (Imamah *et al.*, 2024).

Conclusion

Biodiversity and ecosystems are essential for human life, providing food, medicine, and materials while maintaining ecological balance. However, threats like overexploitation, climate change, and pollution endanger sustainability. Conservation areas preserve biodiversity and support endangered species. Local community involvement through education is crucial for effective conservation. Although economic conflicts may arise, collaboration among governments, communities, and NGOs can yield solutions that benefit both people and ecosystems.

Acknowledgment

The author expresses gratitude to the colleagues from the Doctoral Program in Environmental Science at the State University of Gorontalo, as well as to all parties who have assisted in the completion of this writing.

References

- Al Idrus, A., Ilhamdi, M. L., Hadiprayitno, G., & Mertha, G. (2018). Sosialisasi peran dan fungsi mangrove pada masyarakat di kawasan Gili Sulat Lombok Timur. *Jurnal Pengabdian Magister Pendidikan IPA*, 1(1).
- Alongi, D. M. (2020). Global significance of mangrove blue carbon in climate change mitigation. *Sci*, 2(3), 67.
- Berkes, F. (2017). *Sacred ecology*. Routledge.
- Dewi, S. A. K., Roesli, M., Hidayat, M., Sumarso, S., Wibowo, S. S., Nugroho, B., Heri, A., Wibowo, P. A., & Iswahyudi, G. (2022). Penanaman kembali hutan mangrove sebagai upaya pelestarian lingkungan pada Kebun Raya Mangrove Gunung Anyar Surabaya. *Asthadarma: Jurnal Pengabdian Kepada Masyarakat*, 3(2), 40–50.
- Djamadi, D. A., Faqih, A., Safitri, I., & Baderan, D. W. K. (2024). Analisis Struktur Vegetasi Hutan Mangrove di Pesisir Tabongo Kecamatan Dulupi Kabupaten Boalemo. *Journal of Marine Research*, 13(2), 319-327.
- Faqih, A., & Juramang, R. R. (2023). Keanekaragaman Dan Kelimpahan Jenis Crustacea Di Kawasan Hutan Mangrove Pesisir Langala Kecamatan Dulupi Kabupaten Boalemo. *Jambura Edu Biosfer Journal*, 5(2), 65-71.
- Feller, I. C., Berger, U., Chapman, S. K., Dangremond, E. M., Dix, N. G., Langley, J. A., ... & Simpson, L. T. (2023). Nitrogen addition increases freeze resistance in black mangrove (*Avicennia germinans*) shrubs in a temperate-tropical ecotone. *Ecosystems*, 26(4), 800-814.
- Fikri, M. R. A., Sam'un, M., Lestari, Z. A., & Rahmawati, T. D. (2023). Pemanfaatan hutan mangrove sebagai sumber pendapatan alternatif bagi masyarakat pesisir di desa Sukakarta Karawang. *Jurnal Abditani*, 6(1), 6-10.
- Giri, C. (2023). Frontiers in global mangrove forest monitoring. Remote sensing, 15(15), 3852.
- Hardiansyah, H., & Noorhidayati, N. (2020). Keanekaragaman jenis pohon pada vegetasi mangrove di pesisir Desa Aluh-Aluh Besar Kabupaten Banjar. *Wahana-Bio: Jurnal Biologi dan Pembelajarannya*, 12(2), 71.
- Imamah, T. A., Kurniawan, A., Kamiliyah, N., Asyura, R. R., & Hidayatillah, Y. (2024). Analisis Pemanfaatan Ekowisata Hutan Mangrove Sebagai Sumber Belajar Pada Siswa Sekolah Dasar. *Jurnal Multidisiplin Ilmu Akademik*, 1(6), 363-374.
- Imburi, C. S., Angrianto, R., Tanur, E. A., Widodo, I., & Sitompul, G. A. (2024). Peran hutan mangrove dalam menanggulangi dampak perubahan iklim di wilayah pesisir Indonesia. *Jurnal Geosains West Science*, 2(03), 122-132.
- Islamia, S., & Purwanto, E. (2025). Model Komunikasi Lingkungan dalam Pengembangan Ekowisata Mangrove di Kabupaten Tangerang. *Jurnal Pemberdayaan Ekonomi dan Masyarakat*, 2(1), 14-14.
- Kathiresan, K. (2018). Mangrove forests of India. *Current science*, 976-981.
- Kurniawansyah, A., Susiloningtyas, D., & Manessa, M. D. M. (2023). Mangrove ecosystem management in Indonesia: review, limitation, gap, and knowledge. *Maritime Technology and Research*, 5(3), 262310-262310.
- Maryani, L., Mentari, R. D. P., Susilowati, R., Wihardi, Y., Hasibuan, Z. H., & Agustin, T. (2025). Peran Dan Manfaat Ekosistem Mangrove Terhadap Masyarakat Wilayah Pesisir Muara Sugihan. *Jurnal Abdi Insani*, 12(5), 2065-2072.
- Mongabay. 2019. Polemik Cagar Alam Tanjung Panjang: Tambak hingga TORA. https://www.mongabay.co.id/2019/05/19/polemik-cagar-alam-tanjung-panjang-tambak-hingga-tora-bagian-2/?utm_source=chatgpt.com
- Mumby, P. J. (2017). Embracing a world of subtlety and nuance on coral reefs. *Coral Reefs*, 36(3), 1003-1011.
- Saidah, S., Harudu, L., & Kasmianti, S. (2024). Deskripsi kerusakan ekosistem hutan

mangrove. *Jurnal Penelitian Pendidikan Geografi*, 9(1), 11-23.

Utina, R. (2012). Kecerdasan Ekologis Dalam Kearifan Lokal Masyarakat Bajo Desa Torosiaje Provinsi Gorontalo. In *Prosiding Konferensi Dan Seminar Nasional Pusat Studi Lingkungan Hidup Indonesia Ke* (Vol. 21, No. 5, pp. 14-20).

Utina R. (2014). Bapongka: Studi nilai pendidikan pelestarian ekosistem laut dan pesisir pada masyarakat Bajo. *Jurnal Matsains* 3 (14): 108-116.

Scope : Environment

Article ID : 104

YELLOW BAMBOO'S ROLE IN DISASTER MITIGATION AND SOCIO-ENVIRONMENTAL DYNAMICS IN BIYONGA-BULOTA

Ardiyanto S. Modjo¹, Mahludin H. Baruadi², Sukirman Rahim¹, Dewi W. K. Baderan¹

¹Ilmu Lingkungan, Universitas Negeri Gorontalo, Gorontalo, Indonesia

²Pertanian, Universitas Negeri Gorontalo, Gorontalo, Indonesia

E-mail: *ardiyantosm@ung.ac.id

Abstract

Yellow bamboo provides mechanical soil stabilization, erosion reduction, enhanced infiltration, biomass energy potential, cultural value for local communities. This literature-based study synthesizes recent findings regarding bamboo role within river catchments like Biyonga– Bulota. Results indicate bamboo root networks increase root-soil anchorage, reduce surface runoff, trap sediments, improve soil physical properties, offer livelihood options via product diversification. Primary threats include overharvesting, land-use change, loss of local knowledge. Recommended actions: community-based replanting, strengthened local regulation, cultural integration into conservation planning, product innovation for economic resilience.

Keywords: yellow bamboo; disaster mitigation; riverbank stabilization; community conservation; Biyonga Bulota

Introduction

Bamboo is a plant with high economic, ecological, and socio-cultural value, especially in Indonesia (Luo et al., 2020; Ekawati et al., 2022; Kusumawardhani et al., 2025). The root structure of bamboo helps bind soil particles, stabilize slopes, and reduce erosion risk (Nadir et al., 2024). Bamboo is used not only in crafts and household items but also plays a role in environmental conservation (Lee et al., 2021; Chen et al., 2024). Overexploitation and land-use change threaten bamboo populations, particularly in areas like West Java (Yu et al., 2023; Yamada et al., 2023). Decline occurs due to increasing demand for agricultural land and development, sacrificing bamboo habitats (Hemminger et al., 2022; Zhao et al., 2024). Bamboo holds important cultural significance in Gorontalo, related to traditional ceremonies and local customs (Lee et al., 2021). The loss of bamboo impacts cultural preservation (Mwanja et al., 2024). Community-based approaches and strengthening local knowledge are needed for sustainable management (Branco et al., 2019). Cooperation among communities, government, and NGOs can create effective bamboo management models (Gardner et al., 2020). Education and training in environmentally friendly bamboo cultivation help maintain bamboo populations while improving community economic welfare (Woge, 2024). Strict regulations and community involvement in conservation are crucial.

Method

The study used a literature review with secondary data from journals related to yellow bamboo, disaster mitigation, and environmental sociology. Descriptive analysis described the characteristics of the phenomena and study variables.

Result and Discussion

The distribution of yellow bamboo in Polohungo, Bulota, and Bongohulawa villages shows strong adaptation and efficient vegetative reproduction (Ma et al., 2023). Population decline occurs due to overexploitation and lack of replanting (Ruíz-Sánchez et al., 2019). The root system of yellow bamboo functions to hold soil and water, preventing erosion and landslides in disaster-prone areas (Maddalwar et al., 2024). Bamboo diversity in the study area is moderate with dominance by certain species that increase ecosystem vulnerability (Luan et al., 2021).

Serious conservation is needed to maintain ecological and socio-economic sustainability (Umehruo et al., 2022). The bamboo root system also enhances soil fertility and carbon absorption, aiding climate change mitigation. Bamboo has high socio-cultural value, used in various traditional ceremonies in Gorontalo, strengthening community identity. Bamboo scarcity threatens traditions and economic resources. Education and community involvement are important for sustainable bamboo conservation and management. Collaboration among academics, government, and local communities can create synergies for cultural and ecological preservation. Major challenges include overexploitation, land-use change, and low community awareness (Yirgu et al., 2020). Replanting and empowering local communities are key solutions. Integrating cultural values into watershed management policies supports the ecological and socio-economic sustainability of yellow bamboo.

Conclusion

Yellow bamboo in the Biyonga-Bulota watershed plays a crucial role in disaster mitigation and local cultural preservation. The bamboo root system effectively prevents erosion and maintains soil stability. The socio-cultural value of bamboo strengthens community identity. The declining bamboo population demands active conservation through replanting and community involvement. Recommendations: Planned replanting of yellow bamboo in critical areas along the Biyonga-Bulota watershed to restore populations and maintain ecological functions. Empowerment of local communities through training on environmentally friendly bamboo cultivation and sustainable bamboo product management.

Acknowledgment

Thanks to Gorontalo State University for support enabling this research to be carried out.

References

- Branco, P. S., Merkle, J. A., Pringle, R. M., King, L., Tindall, T., Stalmans, M., & Long, R. A. (2019). An Experimental Test of Community-based Strategies for Mitigating Human–wildlife Conflict Around Protected Areas. *Conservation Letters*, 13(1). <https://doi.org/10.1111/conl.12679>
- Chen, L.-J., Xie, Y., He, T., Chen, L., Rong, J., Chen, L., & Zheng, Y. (2024). Projecting the Impacts of Climate Change, Soil, and Landscape on the Geographic Distribution of Ma Bamboo (*Dendrocalamus Latiflorus* Munro) in China. *Forests*, 15(8), 1321. <https://doi.org/10.3390/f15081321>
- Ekawati, D., Karlinasari, L., Soekmadi, R., & Machfud, M. (2022). The Status of Bamboo Research and Development for Sustainable Use in Indonesia: A Systematic Literature Review. *Iop Conference Series Earth and Environmental Science*, 1109(1), 012100. <https://doi.org/10.1088/1755-1315/1109/1/012100>
- Gardner, C. J., Cripps, G., Day, L. P., Dewar, K. M., Gough, C., Peabody, S., Tahindraza, G., & Harris, A. (2020). A Decade and a Half of Learning From Madagascar's First Locally Managed Marine Area. *Conservation Science and Practice*, 2(12). <https://doi.org/10.1111/csp2.298>
- Hemminger, K., König, H., Månsson, J., Bellingrath-Kimura, S. D., & Nilsson, L. (2022). Winners and Losers of Land Use Change: A Systematic Review of Interactions Between the World's Crane Species (*<i>Gruidae</i>*) and the Agricultural Sector. *Ecology and Evolution*,

12(3). <https://doi.org/10.1002/ece3.8719>

Kusumawardhani, S., Wasilah, D. I., Sabilla, D. M., Saccena, N. D., & Abadi, W. (2025). Utilizing Angklung Production Waste Into Alternative Interior Element to Support Zero-Waste Production in Saung Angklung Udjo, Bandung. *Iop Conference Series Earth and Environmental Science*, 1488(1), 012002. <https://doi.org/10.1088/1755-1315/1488/1/012002>

Lee, B., Rhee, H., Kim, S. B., Lee, J. W., Koo, S., Lee, S.-J., Alounsavath, P., & Kim, Y. (2021). Assessing Sustainable Bamboo-Based Income Generation Using a Value Chain Approach: Case Study of Nongboua Village in Lao PDR. *Forests*, 12(2), 153. <https://doi.org/10.3390/f12020153>

Luan, J., Li, S., Dong, W., Liu, Y., Wang, Y., & Liu, S. (2021). Litter Decomposition Affected by Bamboo Expansion Is Modulated by Litter-mixing and Microbial Composition. *Functional Ecology*, 35(11), 2562–2574. <https://doi.org/10.1111/1365-2435.13911>

Luo, B., Ahmed, S., & Long, C. (2020). Bamboos for Weaving and Relevant Traditional Knowledge in Sansui, Southwest China. *Journal of Ethnobiology and Ethnomedicine*, 16(1). <https://doi.org/10.1186/s13002-020-00418-9>

Ma, S., Li, J., Chen, J., Mei, R. W., Cui, K., & Lan, L. (2023). Research Progress and a Prospect Analysis of Asexual Bamboo Reproduction. *Horticulturae*, 9(6), 685. <https://doi.org/10.3390/horticulturae9060685>

Maddalwar, S., Kumar, T., Tijare, G., Agashe, A., Kotangale, P., Sawarkar, A., & Singh, L. (2024). A Global Perspective on a Bioengineering Approach to Landslide Mitigation Using Bamboo Diversity. In *Advances in Bamboo Science* (Vol. 8). Elsevier B.V. <https://doi.org/10.1016/j.bamboo.2024.100093>

Mwanja, C. K., Ishengoma, R., Banana, A. Y., Terziev, N., & Kalanzi, F. (2024). Effectiveness of Selected Preservatives in Protecting Bamboo Against Termite Attack. *East African Journal of Forestry and Agroforestry*, 7(1), 287–299. <https://doi.org/10.37284/eajfa.7.1.2089>

Nadir, S., Kaushal, R. K., Kumar, A., Jayaraman, D., Reza, S., Ndufa, J. K., Ronoh, E., Elema, M., Thiga, J., & Kumar, M. (2024). Hydrological Response of Bamboo Plantations on Soil–Water Dynamics in Humid and Semi-Arid Coastal Region of Kenya. *Water*, 16(13), 1894. <https://doi.org/10.3390/w16131894>

Ruiz-Sánchez, E., Munguía-Lino, G., Vargas-Amado, G., & Rodríguez, A. (2019). Diversity, Endemism and Conservation Status of Native Mexican Woody Bamboos (Poaceae: Bambusoideae: Bambuseae). *Botanical Journal of the Linnean Society*. <https://doi.org/10.1093/botlinnean/boz062>

Umehruo, C. H., Owolabi, O. A., Aderounmu, B., Rotimi, M. O., & Osabuohien, E. (2022). Environmentally Sustainable Socio-Economic Welfare and Agricultural Employment: Evidence From ECOWAS. *Iop Conference Series Earth and Environmental Science*, 993(1), 012006. <https://doi.org/10.1088/1755-1315/993/1/012006>

Woge, F. D. (2024). Farmers' Practice on the Management and Establishment of Bamboo Stands in Bore Woreda, Guji Zone, Oromia Region, Ethiopia. *African Journal of Climate Change and Resource Sustainability*, 3(1), 345–355. <https://doi.org/10.37284/ajccrs.3.1.2294>

Yamada, T., Imada, K., Aoyagi, H., & Nakabayashi, M. (2023). Does Monocarpic Phyllostachys Nigra Var. Henonis Regenerate After Flowering in Japan? Insights From 3 Years of Observation After Flowering. *Plos One*, 18(6), e0287114. <https://doi.org/10.1371/journal.pone.0287114>

Yirgu, T., Yihunie, Y., Assele, A., & Wogayehu, T. (2020). Land Use/Land Cover Dynamics and Its Environmental Impacts in Kulfo Watershed, Gamo Highlands, South Western Ethiopia. *Journal of Geography Environment and Earth Science International*, 1–11. <https://doi.org/10.9734/jgeesi/2020/v24i230197>

Yu, L., Wei, J., Li, D., Zhong, Y., & Zhang, Z. (2023). Explaining Landscape Levels and Drivers of Chinese Moso Bamboo Forests Based on the Plus Model. *Forests*, 14(2), 397. <https://doi.org/10.3390/f14020397>

Zhao, J., Yu, L., Newbold, T., & Chen, X. (2024). Trends in Habitat Quality and Habitat Degradation in Terrestrial Protected Areas. *Conservation Biology*, 39(2).

Scope : Environment

Article ID : 105

SUSTAINABLE CARBON MANAGEMENT IN PRIMARY ENERGY OF COAL, OIL, AND RENEWABLE ENERGY

Yanto Sidik Pratiknyo^{1*}, Wilson Bangun², Zainur Hidayah¹, Roni Kambara³

¹Universitas Terbuka, Tangerang, Indonesia

²Universitas Maranatha, Bandung, Indonesia

³Universitas Sultan Agung Tirtayasa, Serang Indonesia

E-mail: *530055053@ecampus.ut.ac.id

Abstract

The impact of global warming in recent years has increasingly made it clear that energy transformation is now a crucial component in achieving carbon neutrality. Problem research goals. Therefore, this study focuses on the relationship between carbon emissions and energy transformation specifically. Methods. A time series approach from 1990 to 2023 is used in this study to investigate the energy transition problem. This study examines the nonlinear relationships between variations in carbon emissions and the utilization of coal, gas, petroleum, and renewable energy. The results. There is a significant correlation between CO₂ emission variables, renewable energy, and coal, with both significant figures less than 0.05. Conclusion. It appears that the management of coal and renewable energy has a significant impact on carbon emissions. Enhanced transition management of other energy sources, particularly gas and petroleum, is required to achieve a greater reduction in carbon emissions.

Key words: sustainability; carbon emission; primary energy; management, renewable,

Introduction

The increasingly evident impacts of global climate change in recent years have underscored the urgency of energy transformation as a crucial pathway toward achieving carbon neutrality (Feng & Zhao, 2022). Carbon dioxide (CO₂) remains the dominant greenhouse gas responsible for global warming, and its environmental implications inevitably extend to economic dimensions. Various factors contribute to the rise of CO₂ emissions, among which income levels and energy consumption play significant roles (Zaekhan & Nachrowi, 2015). A comparative study across 15 nations revealed a negative relationship between ecological footprint and renewable energy consumption, while the correlation between ecological footprint and natural resource abundance was positive in both low- and high-income countries. Consequently, these nations are strongly encouraged to invest in renewable energy technologies and research to facilitate a transition toward sustainable energy use (Ullah et al., 2021).

In the pursuit of Net Zero Energy goals, renewable energy solutions particularly for heating, cooling, and electricity generation in buildings integrated with thermal energy storage are of paramount importance. The implementation of efficient building systems powered by renewable sources is therefore essential. Policy interventions are also necessary to ensure that the global transition toward sustainable energy and power systems remains technically viable and economically beneficial. Simultaneously, strategies to enhance the efficiency of non-renewable

resources should be integrated, as these continue to contribute significantly to energy stability and cost reduction (Zhang et al., 2022).

Furthermore, the development of mechanisms to increase storage capacity and mitigate CO₂ leakage risks plays a vital role in ensuring sustainable carbon management (Joel & Oguanobi, 2024). Efforts to minimize carbon footprints not only reduce operational costs but also improve employee satisfaction and strengthen corporate reputation. The concept of “transition” thus represents a foundational principle in policy frameworks aimed at mitigating the adverse socio-economic effects of shifting toward a low-carbon society (Banerjee & Schuitema, 2022). To sustain the technical and economic feasibility of the global energy transition, large-scale renewable energy deployment must be complemented by initiatives that optimize the performance of non-renewable resources, which continue to play a pivotal role in system stabilization and cost efficiency (Kabeyi & Olanrewaju, 2022).

Methods

The growing complexity of the challenges encountered in transitioning toward a low-carbon energy system has attracted significant scholarly attention. In this context, the present study seeks to systematically identify and categorize these challenges through a comprehensive literature review of publications spanning from 2006 to 2023. A total of 123 relevant articles were analyzed, resulting in the identification of seventeen key challenges, which were subsequently grouped into five main dimensions: social, economic, environmental, technical, and institutional (Kamali Saraji & Streimikiene, 2023).

Employing a balanced panel dataset from 30 Chinese provinces covering the years 2004–2017, Dong et al., (2021) examined the causal relationship between the low-carbon energy transition and energy poverty using a nonparametric panel causality method within quantile regressions. Additionally, the generalized method of moments (GMM) was applied to evaluate the influence of green financing, CO₂ emissions, and economic growth on environmental investment in developing countries during 2000–2021. Recognizing the heterogeneity among urban areas, Shen et al., (2023) emphasized that each city requires a tailored low-carbon transition roadmap rather than adopting a uniform approach. Over time, research in this domain has increasingly employed qualitative methodologies, with a noticeable deepening in both thematic focus and analytical rigor.

Empirical findings suggest that the establishment of international climate agreements can stimulate research intensity concerning low-carbon energy transitions. To further explore the dynamic interactions among influencing factors, Hwang & Venter, (2025) conducted a dynamic threshold regression to investigate the nonlinear effects of fossil fuel dependence, the digital economy, and institutional quality on renewable energy deployment.

On another front, Ullah et al. (2021) investigated the asymmetric, nonlinear relationship between ecological footprint and renewable energy consumption by extending the traditional linear model into a nonlinear framework. This analytical refinement builds upon the classical Cobb–Douglas production function (Cobb & Douglas, 1928; Mansfield, 1975; Varian, 2010), formulated as follows:

$$CO(C, G, P, R) = A \prod_{i=C,G,F,R} X_i^{\alpha_i} \quad (1)$$

Where:

CO = Carbon emission

C = Coal

G = Gas

P = Petroleum

R = Renewable

Equation will be as follow:

$$CO(C, G, P, R) = A C^{\alpha} G^{\beta} P^{\gamma} R^{\delta} \quad (2)$$

Where:

A = constant. α, β, γ = parameter

Convert to the naturalist logarithmic

$$\ln CO(C, G, P, R) = \ln C + \alpha \ln G + \beta \ln P + \gamma \ln R \quad (3)$$

Results & Discussion

The data processed from 1990 - 2022, then transferred into natural logarithmic form as in Table 1 Indonesia Primary Energy.

Table 1: Indonesia Primary Energy

Year	T /capita	Quad BTU				Renewable	LnCO	LnC	LnG	LnP	LnR
		CO2	Coal	Gas	Petroleum						
1990	0.882	0.245	1.762	3.066	0.027	-0.126	-1.406	0.566	1.120	-3.612	
1991	0.935	0.324	1.996	3.339	0.028	-0.067	-1.127	0.691	1.206	-3.576	
1992	0.961	0.451	2.105	3.161	0.034	-0.040	-0.796	0.744	1.151	-3.381	
1993	1.034	0.611	2.150	3.185	0.031	0.033	-0.493	0.765	1.158	-3.474	
1994	1.082	0.675	2.405	3.349	0.032	0.079	-0.393	0.878	1.209	-3.442	
1995	1.196	0.879	2.439	3.341	0.035	0.179	-0.129	0.892	1.206	-3.352	
1996	1.240	1.111	2.570	3.331	0.038	0.215	0.105	0.944	1.203	-3.270	
1997	1.334	1.238	2.585	3.290	0.028	0.288	0.213	0.950	1.191	-3.576	
1998	1.326	1.452	2.473	3.231	0.045	0.282	0.373	0.905	1.173	-3.101	
1999	1.386	1.754	2.731	3.111	0.044	0.327	0.562	1.005	1.135	-3.124	
2000	1.384	1.775	2.438	2.936	0.051	0.325	0.574	0.891	1.077	-2.976	
2001	1.459	2.163	2.058	2.780	0.061	0.378	0.771	0.722	1.022	-2.797	
2002	1.463	2.357	2.249	2.586	0.056	0.381	0.857	0.810	0.950	-2.882	
2003	1.571	2.674	2.387	2.445	0.053	0.452	0.984	0.870	0.894	-2.937	
2004	1.580	3.239	2.211	2.303	0.057	0.458	1.175	0.793	0.834	-2.865	
2005	1.571	3.777	2.181	2.260	0.060	0.451	1.329	0.780	0.815	-2.813	
2006	1.639	4.729	2.370	2.128	0.059	0.494	1.554	0.863	0.755	-2.830	
2007	1.695	5.461	2.640	2.020	0.072	0.528	1.698	0.971	0.703	-2.631	
2008	1.654	5.847	2.695	2.086	0.090	0.503	1.766	0.991	0.735	-2.408	
2009	1.691	6.135	2.787	2.041	0.083	0.526	1.814	1.025	0.713	-2.489	
2010	1.801	7.345	3.180	2.048	0.120	0.589	1.994	1.157	0.717	-2.120	
2011	2.004	7.195	2.935	1.949	0.141	0.695	1.973	1.077	0.667	-1.959	
2012	1.996	7.822	2.855	1.875	0.157	0.691	2.057	1.049	0.629	-1.852	
2013	1.856	9.652	2.841	1.791	0.200	0.619	2.267	1.044	0.583	-1.609	
2014	1.951	9.405	2.827	1.721	0.218	0.669	2.241	1.039	0.543	-1.523	
2015	1.957	9.514	2.802	1.707	0.135	0.672	2.253	1.030	0.535	-2.002	
2016	1.916	9.271	2.761	1.799	0.246	0.650	2.227	1.016	0.587	-1.402	
2017	2.004	9.405	2.827	1.721	0.218	0.695	2.241	1.039	0.543	-1.523	
2018	2.213	9.514	2.802	1.707	0.135	0.794	2.253	1.030	0.535	-2.002	
2019	2.339	9.271	2.761	1.799	0.246	0.850	2.227	1.016	0.587	-1.402	
2020	2.162	9.261	2.775	1.723	0.210	0.771	2.226	1.021	0.544	-1.561	
2021	2.238	11.011	2.779	1.655	0.434	0.805	2.399	1.022	0.504	-0.835	
2022	2.355	12.178	2.582	1.594	0.504	0.857	2.500	0.949	0.466	-0.685	
2023	2.399	11.100	2.270	1.500	0.500	0.875	2.407	0.820	0.405	-0.693	

Data from Table 1: Indonesia Primary Energy, then processed using SPSS software

Table 2: Coefficients

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.356	.115		3.091	.004
	LnC	.231	.033	.948	7.065	.000
	LnG	-.118	.122	-.055	-.973	.339
	LnP	.191	.137	.186	1.398	.173
	LnR	.088	.029	.276	3.071	.005

a. Dependent Variable: LnCO

$$CO(C, G, P, R) = 0.356 C^{0.231} G^{-0.118} P^{0.191} R^{0.088}$$

Based on the results presented in Table 2: Coefficients obtained from SPSS analysis, the variables representing coal and renewable energy exhibit significance levels below 0.05. This indicates that both factors have a statistically significant nonlinear influence on carbon emissions.

In contrast, the variables for gas and petroleum display insignificant coefficients, suggesting that their impacts on carbon emissions are not statistically meaningful.

The realization of the Paris Agreement's objectives necessitates the extensive deployment of low-carbon energy technologies. Nonetheless, the establishment, operation, and maintenance of such systems inevitably require substantial energy inputs, a considerable portion of which still originates from fossil fuels (Slameršak et al., 2022). In light of the challenges and opportunities identified in the transition process, several strategic actions have been proposed to guide this transformation. These include the expansion of green financing mechanisms, the strengthening of international cooperation, and the enhancement of green recovery initiatives to support sustainable energy development (Tian et al., 2022).

Moreover, integrating carbon-related costs such as carbon pricing, emission trading systems, and carbon taxes into the energy market can promote the optimization of renewable power systems. By incorporating the financial implications of abrupt variations in renewable energy generation into the objective function, the efficiency and reliability of renewable integration can be improved (Kyriakopoulos et al., 2022). Finally, the pursuit of carbon neutrality continues to face critical challenges related to the urgency of the transition, technological constraints, and evolving policy frameworks, all of which demand coordinated and adaptive responses (Hwang & Venter, 2025).

Conclusion

The growing urgency for a rapid transition toward clean energy has become increasingly evident in response to global climate change and rising greenhouse gas emissions. Exploring and utilizing renewable energy sources such as wind and solar power represents an effective pathway to optimizing energy structures and enhancing overall efficiency (Shen et al., 2023). As fossil fuels, mainly coal, natural gas, and oil, still accounted for approximately 61.3% of global electricity generation in 2020 (Kabeyi & Olanrewaju, 2022), the global energy system must accelerate its transformation by improving energy efficiency, fostering a circular and sustainable bioeconomy, and promoting the adoption of renewable resources such as solar, wind, hydropower, nuclear, and hydrogen (Rabbi et al., 2022). The vision of a sustainable energy future powered by renewable sources is achievable, as highlighted by recent research offering pathways toward this transformation (Saleh & Hassan, 2024). However, without careful planning, the transition may lead to unintended consequences such as energy sprawl, emphasizing the importance of developing decentralized clean energy communities as viable alternatives to conventional centralized systems (Wehbi, 2024).

The findings of this study further underscore that energy transformation is crucial for achieving carbon neutrality. Through a time series analysis covering the period from 1990 to 2023, the nonlinear relationships between carbon emissions and primary energy sources including coal, gas, petroleum, and renewables were examined. The results reveal that coal and renewable energy exhibit significant associations with carbon emissions, as both variables demonstrated significance levels below 0.05. This indicates that effective management of these two energy sources can substantially influence emission reduction outcomes. Conversely, gas and petroleum showed weaker relationships, suggesting that improved management and optimization of these sectors are essential to further minimize carbon emissions. Overall, achieving carbon neutrality requires a coordinated approach that integrates renewable energy expansion with efficiency improvements across all primary energy systems.

References

Banerjee, A., & Schuitema, G. (2022). How just are just transition plans? Perceptions of decarbonisation and low-carbon energy transitions among peat workers in Ireland. *Energy Research and Social Science*, 88(October 2021). <https://doi.org/10.1016/j.erss.2022.102616>

- Cobb, C. W., & Douglas, P. H. (1928). A Theory of Production. *The American Economic Review*. <https://msuweb.montclair.edu/~lebelp/CobbDouglasProdAER1928.Pdf>, 18(1), 139–165.
- Dong, K., Ren, X., & Zhao, J. (2021). How does low-carbon energy transition alleviate energy poverty in China? A nonparametric panel causality analysis. *Energy Economics*, 103(September), 105620. <https://doi.org/10.1016/j.eneco.2021.105620>
- Feng, Y., & Zhao, T. (2022). Exploring the Nonlinear Relationship between Renewable Energy Consumption and Economic Growth in the Context of Global Climate Change. *International Journal of Environmental Research and Public Health*, 19(23). <https://doi.org/10.3390/ijerph192315647>
- Hwang, Y. K., & Venter, A. (2025). The impact of the digital economy and institutional quality in promoting low-carbon energy transition. *Renewable Energy*, 238(September 2024), 121884. <https://doi.org/10.1016/j.renene.2024.121884>
- Joel, O. T., & Oguanobi, V. U. (2024). Future directions in geological research impacting renewable energy and carbon capture: A synthesis of sustainable management techniques. *European Journal of Social Psychology*, 40(2), 366–374.
- Kabeyi, M. J. B., & Olanrewaju, O. A. (2022). Sustainable Energy Transition for Renewable and Low Carbon Grid Electricity Generation and Supply. *Frontiers in Energy Research*, 9(March), 1–45. <https://doi.org/10.3389/fenrg.2021.743114>
- Kamali Saraji, M., & Streimikiene, D. (2023). Challenges to the low carbon energy transition: A systematic literature review and research agenda. *Energy Strategy Reviews*, 49(August), 101163. <https://doi.org/10.1016/j.esr.2023.101163>
- Kyriakopoulos, G. L., Streimikiene, D., & Baležentis, T. (2022). Addressing Challenges of Low-Carbon Energy Transition. *Energies*, 15(15), 1–7. <https://doi.org/10.3390/en15155718>
- Mansfield, E. (1975). *Microeconomics : theory and applications*. New York : Norton.
- Oloruntosin Tolulope Joel, & Vincent Ugochukwu Oguanobi. (2024). Future directions in geological research impacting renewable energy and carbon capture: A synthesis of sustainable management techniques. *International Journal of Frontiers in Science and Technology Research*, 6(2), 071–083. <https://doi.org/10.53294/ijfstr.2024.6.2.0039>
- Rabbi, M. F., Popp, J., Máté, D., & Kovács, S. (2022). Energy Security and Energy Transition to Achieve Carbon Neutrality. *Energies*, 15(21). <https://doi.org/10.3390/en15218126>
- Saleh, H. M., & Hassan, A. I. (2024). The challenges of sustainable energy transition: A focus on renewable energy. *Applied Chemical Engineering*, 7(2), 1–24. <https://doi.org/10.59429/ace.v7i2.2084>
- Shen, Y., Shi, X., Zhao, Z., Sun, Y., & Shan, Y. (2023). Measuring the low-carbon energy transition in Chinese cities. *IScience*, 26(1), 105803. <https://doi.org/10.1016/j.isci.2022.105803>
- Slameršak, A., Kallis, G., & O'Neill, D. W. (2022). Energy requirements and carbon emissions for a low-carbon energy transition. *Nature Communications*, 13(1), 1–15. <https://doi.org/10.1038/s41467-022-33976-5>
- Tian, J., Yu, L., Xue, R., Zhuang, S., & Shan, Y. (2022). Global low-carbon energy transition in the post-COVID-19 era. *Applied Energy*, 307(November 2021), 118205. <https://doi.org/10.1016/j.apenergy.2021.118205>
- Ullah, A., Ahmed, M., Raza, S. A., & Ali, S. (2021). A threshold approach to sustainable development: Nonlinear relationship between renewable energy consumption, natural resource rent, and ecological footprint. *Journal of Environmental Management*, 295(March), 113073. <https://doi.org/10.1016/j.jenvman.2021.113073>
- Varian, H. R. (2010). *Intermediate Microeconomics A Modern Approach*. W. W. Norton & Company, Inc., 500 Fifth Avenue, New York, N.Y. 10110.
- Wehbi, H. (2024). Powering the Future: An Integrated Framework for Clean Renewable Energy Transition. *Sustainability (Switzerland)*, 16(13). <https://doi.org/10.3390/su16135594>
- Zaekhan, Z., & Nachrowi, N. D. (2015). The Impact of Renewable Energy and GDP per Capita

on Carbon Dioxide Emission in the G-20 Countries. *Economics and Finance in Indonesia*, 60(2), 145. <https://doi.org/10.7454/efi.v60i2.71>

Zhang, S., Ocloń, P., Klemeš, J. J., Michorczyk, P., Pielichowska, K., & Pielichowski, K. (2022). Renewable energy systems for building heating, cooling and electricity production with thermal energy storage. *Renewable and Sustainable Energy Reviews*, 165(January). <https://doi.org/10.1016/j.rser.2022.112560>

Scope : Environment
Article ID : 106

ENVIRONMENTAL MANAGEMENT STRATEGIES IN THE TRANSITION TO LOW-CARBON SMART CITIES: CHALLENGES AND OPPORTUNITIES

Ardiyanti*, Desy Safitri, and Agung Purwanto

Environmental Management Study Program, Postgraduate Program, Universitas Negeri Jakarta, Indonesia

E-mail: *ardiyanti@mhs.unj.ac.id

Abstract

Rapid urbanization has intensified environmental challenges, pushing cities to implement sustainable management strategies. This study explores environmental management approaches that facilitate the transition toward low-carbon smart cities through a systematic review of policy frameworks, technological innovations, and community-based initiatives. The analysis identifies critical obstacles, including fragmented governance, insufficient financing, and weak policy enforcement, which hinder effective implementation. Conversely, it highlights key opportunities such as digital innovation, green infrastructure development, and cross-sector collaboration that can enhance sustainability outcomes. The findings emphasize that integrated environmental governance, long-term strategic planning, and inclusive stakeholder engagement are fundamental to achieving resilience and sustainability. Ultimately, the study emphasizes the value of aligning governance mechanisms with technological and social innovation to advance the transformation of cities into low-carbon smart systems capable of adapting to environmental and societal changes.

Keywords: environmental management; low carbon; smart cities; sustainability; governance

Introduction

The rapid pace of global urbanization has become one of the major challenges of the twenty-first century, reshaping environmental, social, and economic systems. Expanding cities contribute to air pollution, waste accumulation, rising energy use, and ecosystem degradation. Urban areas now generate over 70% of global carbon emissions, making them both drivers of economic growth and key sources of environmental harm. This dual role highlights the urgency of developing sustainable urban management strategies. In response, the concept of the low-carbon smart city has emerged, integrating environmental management, digital technology, and participatory governance to achieve long-term sustainability (Bibri & Krogstie, 2017).

A low carbon smart city goes beyond clean technology adoption, emphasizing systemic change in governance, planning, and citizen engagement. Through tools like IoT, artificial intelligence, and data-driven infrastructure, such cities aim to optimize energy use, mobility, and waste systems while enhancing social inclusivity. Yet, challenges remain; fragmented governance, limited investment, and weak policy coordination hinder implementation. Recent

studies stress that sustainability requires more than technological innovation; it depends on institutional reform, coherent policy, and behavioral change. Cities like Singapore and Copenhagen exemplify success through integrating technology with strong governance and civic participation (Caragliu & Del, 2020).

This study examines strategies for advancing low-carbon smart cities through a systematic review of policy frameworks, technological innovations, and community practices. The findings aim to bridge theory and practice by offering insights for policymakers and planners to develop adaptive, integrated, and equitable urban sustainability frameworks.

Method

This study employed a Systematic Literature Review (SLR) approach to examine environmental management strategies that facilitate the transition toward low-carbon smart cities. The review synthesized information from academic journal articles, policy documents, and case studies sourced from reputable databases such as Scopus, ScienceDirect, and SpringerLink. Selection criteria focused on studies addressing sustainability, governance, and urban innovation related to low-carbon transitions. The literature was systematically reviewed to identify prevailing themes, strategic approaches, and key challenges in environmental management for sustainable urban development. This method allows for comprehensive and evidence-based insights into policy and governance frameworks that support the realization of resilient, low-carbon smart cities.

Result and Discussion

The rapid growth of urbanization in the twenty-first century presents both vast opportunities for innovation and serious environmental challenges. Studies reveal that cities produce over 70% of global CO₂ emissions, mainly from industrial activity, transport, and fossil fuel-based energy use (Zhu et al., 2024). Urban expansion intensifies resource consumption, waste generation, and ecosystem degradation, which in turn harms air and water quality and reduces urban livability. Poor planning and the spread of impervious surfaces further heighten urban heat and flood risks (Balany et al., 2020). Consequently, cities have become both key drivers and potential solutions to global environmental change, emphasizing the need for low-carbon and sustainable urban governance.

To address these growing environmental challenges, environmental management has become a key driver in advancing low-carbon smart cities. Research identifies several strategic pathways supporting this shift. The adoption of renewable energy technologies, such as solar panels, wind turbines, and bioenergy, offers a direct route to reducing urban carbon emissions (Chen et al., 2019). At the same time, smart technologies like IoT, AI, and big data analytics enhance environmental governance by enabling real-time monitoring, predictive control, and efficient management of energy, transportation, and waste systems (Yigitcanlar et al., 2019). Moreover, integrating green infrastructure, including green roofs, urban forests, and permeable surfaces, plays a dual role in lowering emissions and strengthening urban ecosystem resilience (Anguelovski et al., 2016).

The circular economy has become a crucial aspect of sustainable environmental management, emphasizing efficient resource use, waste reduction, and material recovery in urban systems. It encourages cities to redesign production and consumption toward closed-loop models that extend product lifecycles and lessen dependence on raw materials. At the same time, sustainable mobility, including electric public transport, shared mobility, and walkable city design contributes to emission reduction and social inclusivity. These efforts highlight the importance of integrated governance, ensuring coordination among multiple stakeholders and aligning environmental, economic, and social goals. However, cities still encounter significant barriers in

implementing low-carbon transitions. Fragmented governance and institutional silos hinder policy integration (De Jong et al., 2015), while financial limitations, especially in developing nations, restrict investments in renewable energy, waste systems, and smart infrastructure. Furthermore, technological disparities persist, as advanced digital tools and data management systems remain concentrated in wealthier cities, limiting innovation in smaller municipalities.

Another critical yet often overlooked barrier to low-carbon transitions lies in social and behavioral resistance. Public unwillingness to modify consumption patterns, transport preferences, and waste practices frequently weakens sustainability initiatives (Meijer & Bolívar, 2016). This challenge is intensified by the policy implementation gap, where ambitious plans fail to translate into practical outcomes (Yigitcanlar et al., 2019). Many urban programs remain top-down, lacking participatory mechanisms and institutional continuity (de Jong et al., 2015). Nevertheless, several opportunities are reshaping this landscape. Green financing tools, including climate bonds, carbon credits, and sustainability-linked investments, are supporting low-carbon infrastructure. Advances in digital innovation, such as AI-driven planning, sensor-based monitoring, and blockchain for carbon tracking, are improving transparency in environmental governance (Zhu et al., 2024). In parallel, public–private partnerships (PPPs) have proven vital in mobilizing resources for renewable energy, waste management, and sustainable transport. Moreover, strengthening community participation is essential to ensure inclusive and lasting change. Empowering citizens as active contributors enhances policy legitimacy and fosters social adaptation. Incorporating environmental justice within smart city planning helps distribute the benefits of low-carbon transitions, such as clean air, efficient transport, and energy equity, more fairly across social groups (Meijer & Bolívar, 2016; Yigitcanlar et al., 2019).

In summary, building low-carbon smart cities demands an integrated approach that aligns technology, governance, finance, and community participation. Innovation must be supported by strong institutions and inclusive policies to ensure lasting impact. The future of sustainable cities relies on effective coordination, financial mobilization, and citizen engagement. Combining digital intelligence with ecological awareness through transparent and collaborative governance offers the clearest path toward resilient and equitable urban development (De Jong et al., 2018; Yigitcanlar et al., 2019).

Conclusion

The shift toward low-carbon smart cities is essential to address the environmental pressures of urban growth and rising energy demands. Through integrated environmental management, encompassing renewable energy, smart technologies, green infrastructure, and circular economy models, cities can curb emissions and strengthen resilience. However, challenges such as weak governance coordination, limited funding, and low public engagement remain significant barriers. Advancements in global sustainability agendas, digital transformation, and participatory governance present new pathways for progress. Ultimately, achieving sustainable low-carbon urban systems depends on coherent policies, cross-sectoral cooperation, and active civic involvement to secure enduring environmental and socio-economic benefits.

Acknowledgment

The author sincerely thanks all individuals and institutions that supported this research. Special appreciation is given to academic advisors and reviewers for their valuable insights, as well as to the research library and database services for providing essential resources. Gratitude is also extended to colleagues and professionals who contributed ideas and discussions that enriched this study.

References

- Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K., & Teicher, H. (2016). Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South: Critical Perspectives from the Global North and South. *Journal of Planning Education and Research*, 36(3), 333-348.
<https://doi.org/10.1177/0739456X16645166>
- Balany, F., Ng, A. W., Muttill, N., Muthukumaran, S., & Wong, M. S. (2020). Green Infrastructure as an Urban Heat Island Mitigation Strategy—A Review. *Water*, 12(12), 3577.
<https://doi.org/10.3390/w12123577>
- Bibri, S. E., Alexandre, A., Sharifi, A., & Krogstie, J. (2023). Environmentally sustainable smart cities and their converging AI, IoT, and big data technologies and solutions: An integrated approach to an extensive literature review. *Energy Informatics*, 6, Article 9.
<https://doi.org/10.1186/s42162-023-00259-2>
- Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society*, 31, 183-212.
<https://doi.org/10.1016/j.scs.2017.02.016>
- Caragliu, A., & Del Bo, C. (2020). *Do smart city policies work?* In B. Daniotti, C. Corbelle-Rico, & L. Grosso (Eds.), *Digital Transformation of the Design, Construction and Management Processes of the Built Environment* (pp. 149–159). Springer. https://doi.org/10.1007/978-3-030-33570-0_14
- Chen, B., Xiong, R., Li, H., Sun, Q., & Yang, J. (2019). Pathways for sustainable energy transition. *Journal of Cleaner Production*, 228, 1564-1571.
<https://doi.org/10.1016/j.jclepro.2019.04.372>
- De Jong, M., Joss, A., Schraven, D., Zhan, C., & Weijnen, M. P. C. (2015). Sustainable-smart-resilient-low carbon-eco-knowledge cities: Making sense of a multitude of concepts promoting sustainable urbanization. *Journal of Cleaner Production*, 109, 25–38.
<https://doi.org/10.1016/j.jclepro.2015.02.004>
- Guo, Q., Wang, Y., & Dong, X. (2022). Effects of smart city construction on energy saving and CO₂ emission reduction: Evidence from China. *Applied Energy*, 313, Article 118879.
<https://doi.org/10.1016/j.apenergy.2022.118879>
- Huda, N. (2023). Integration of Data-Driven Technologies in Smart Grids for Resilient and Sustainable Smart Cities: A Comprehensive Review. *ArXiv* (Cornell University). <https://doi.org/10.48550/ARXIV.2301.08814>
- Li, B., Liu, S., Song, Y., & Cui, Z. (2025). The coordination effects of low-carbon city pilot and smart city pilot on urban land green use efficiency: Evidence from a quasi-natural experiment in China. *Frontiers in Earth Science*, 13, Article 1630832.
<https://doi.org/10.3389/feart.2025.1630832>
- Meijer, A., & Bolívar, M. P. R. (2016). Governing the smart city: A review of the literature on smart urban governance. *International Review of Administrative Sciences*, 82(2), 392-408.
<https://doi.org/10.1177/0020852314564308>
- Raharjana, I. K. (2019). *A systematic literature review of environmental concerns in smart cities*. IOP Conference Series: Earth and Environmental Science, 245(1), Article 012031.
<https://doi.org/10.1088/1755-1315/245/1/012031>
- Ramli, H., Azizi, Z. M., & Thurairajah, N. (2024). Sustainable Smart City Technologies and Their Impact on Users' Energy Consumption Behaviour. *Energies*, 17(4), 771.
<https://doi.org/10.3390/en17040771>
- Shao, J., & Min, B. (2025). *Sustainable development strategies for Smart Cities: Review and*

<https://doi.org/10.1016/j.cities.2024.105663>

Sharifi, A., Allam, Z., Bibri, S. E., & Khavarian-Garmsir, A. R. (2023). *Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits and trade-offs*. *Cities*, 146, Article 104659. <https://doi.org/10.1016/j.cities.2023.104659>

Sharifi, A., & Yamagata, Y. (2022). Smart cities and climate-resilient urban planning. *Environment and Planning B: Urban Analytics and City Science*, 49(5), 1347-1353. <https://doi.org/10.1177/23998083221102400>

Szpilko, D., Fernando, X., Nica, E., Budna, K., Rzepka, A., & Lăzăroiu, G. (2024). Energy in Smart Cities: Technological Trends and Prospects. *Energies*, 17(24), 6439. <https://doi.org/10.3390/en17246439>

Tan, S. Y., & Taeihagh, A. (2020). Smart City Governance in Developing Countries: A Systematic Literature Review. *Sustainability*, 12(3), 899. <https://doi.org/10.3390/su12030899>

Yigitcanlar, T., Kamruzzaman, M., Foth, M., Sabatini-Marques, J., da Costa, E. M., & Ioppolo,

G. (2019). Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society*, 45, 348-365. <https://doi.org/10.1016/j.scs.2018.11.033>

Zhu, X., Li, D., Zhu, S., & Ting, S. A. (2024). Is smart city low-carbon? Evidence from China. *Heliyon*, 10(16), Article e35569. <https://doi.org/10.1016/j.heliyon.2024.e35569>

RIVERBANKS AS GREEN INFRASTRUCTURE IN URBAN AREAS

Nurlita Pertiwi

Engineering Faculty Universitas Negeri Makassar, Makassar, Indonesia

E-mail: *nurlita.pertiwi@unm.ac.id

Abstract

Urban riverbanks have ecological and socio-economic role in the community. However, ecologically, riverbanks significantly influence the quality of river flow through the presence of vegetation and other infrastructure. Furthermore, the need for space has led to intensive riverbank utilization. This article outlines the ecological, social, and economic roles of urban communities in riverbank management. Furthermore, the implementation of riparian area policies is a crucial instrument in realizing riverbanks' function as green infrastructure.

Keywords: Ecological role, Social and economic, Urban space utilization

Introduction

Urban areas, as areas with high population density, are characterized by rapid infrastructure development. The various needs of the population lead to high land use. Land use in urban areas can have various impacts on both the urban ecosystem and the quality of life of its residents. (Ciommi et al., 2018; Profiroiu et al., 2020). On the other hand, urban land management also requires conservation space to maintain ecosystem balance (Bille et al., 2023; Wu et al., 2021). Riverbank land holds significant appeal for communities. They utilized the riverbank land sanitation and recreation. However, human activity along riverbanks can create conflicts between development and environmental protection (Das & Sarkar, 2025). In terms of utilization, riverbanks serve as a crucial medium for community economic activity.

Urban infrastructure is built to meet community needs. However, these facilities must also support the city's sustainability and progress (Qiao et al., 2022; Sun & Cui, 2018). Housing development or road infrastructure along riverbanks results in the loss of protective ecosystems. Consequently, the river's function as a water channel declines, characterized by sedimentation and flooding.

The author conducted a literature review using international journals to identify the concept of riverbank development as green infrastructure. Riverbank land management patterns that integrate ecological strengthening with community land needs contribute to the development of sustainable urban development practices.

Green Infrastructure

The study of green infrastructure is not only focusing in environmental science researchers but has also developed from various disciplinary perspectives. Green infrastructure studies generally focus on improving urban environmental quality. This is characterized by concerns about worsening environmental quality. Many cities in Indonesia pose a risk of declining human quality of life's large cities because their dense population and mobility. The researcher outlines three important benefits of green infrastructure: providing environmental services to maintain

ecosystem capacity, meeting community needs for well-being, and providing environmental facilities in cities. Green infrastructure facilitates interactions between biophysical structures, biodiversity, and local ecosystem processes (Fang et al., 2023; Lee & Song, 2019). These facilities are developed with the hope that ecosystem services will continue to support the quality of the biotic and abiotrophic environment (Ying et al., 2022).

Green infrastructure functions as a provider of clean air and as a facility to support community life. Green infrastructure takes seven forms, depending on the area and spatial use. (Figure 1)

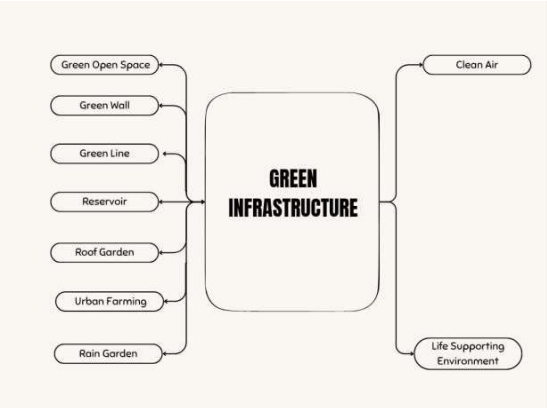


Figure 1. Various Forms of Green Infrastructure.

Green open space is the urban space that functions ecologically, socially, and aesthetically because it is filled with natural and artificial vegetation to create a balance between the artificial and natural environments. This space can be public or accessible to many people. However, there are also private green open spaces, such as office or residential parks (Harjanti & Anggraini, 2020; Pertiwi & Lullulangi, 2018).

Green open space as one of the green facilities is the main choice in improving the poor physical condition of urban areas. Green wall is a vertical garden that wraps around a building's walls. The green plants that cover the walls of high-rise buildings enhance the building's aesthetics and absorb carbon dioxide from the air. This green facade system is simpler, more cost-effective, and suitable for tropical climates like Indonesia. Climbers or creepers are allowed to grow on the walls with the help of netting to spread evenly and shape the building's (de Manuel et al., 2021; Fang et al., 2023). Reservoirs, or water reservoirs in urban areas, can also serve as green infrastructure. Reservoirs, whether natural or artificial, are designed to store or infiltrate water. Mini-dams, built to slow flow, trap sediment, and enhance infiltration, are one form of facility that can mitigate urban microclimate conditions.

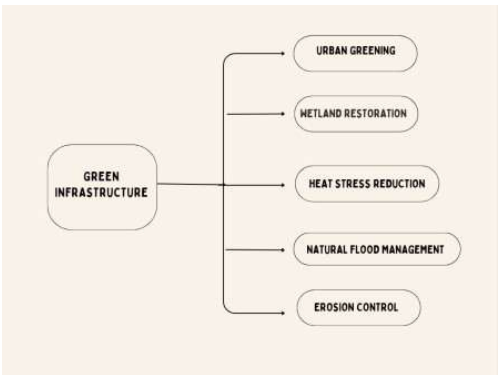


Figure 2. The Function of Green Infrastructure (Lee & Song, 2019; Monteiro et al., 2020; Wang & Banzhaf, 2018).

In general, Figure 2 illustrates the function of green urban infrastructure. Besides greening the city, these facilities can reduce urban air pollution. Both of these functions are crucial for providing a comfortable climate for urban residents. In addition to protecting urban water resources, green infrastructure can also regulate water flow and prevent flooding.

Riverbanks as Green Infrastructure

Riverbanks play a crucial ecological role in green infrastructure systems. The boundary between wet and dry zones in river ecosystems has unique ecological characteristics. Naturally, riverbanks play a role in filtering sediment, maintaining water quality, wildlife habitat, and ecosystem balance. However, overuse has led to the conversion of these areas into residential areas or other facilities, resulting in the loss of their ecological function and the destruction of urban ecosystem. Several facts about urban riverbank management as green infrastructure are presented below:

- The Cheonggyecheon Project in Seoul, South Korea.

The local government focused on environmental and ecological restoration in Seoul City. The government restored the river's function by demolishing an overpass that had previously damaged the river's ecosystem. The restoration of approximately 5.6 km of the river's flow was carried out by reactivating the water flow by building an urban green corridor. The government maintained the river's sustainability by pumping water from the Han River. The results of this strategy were lower air temperatures, improved air quality, and the emergence of new biodiversity (flora and fauna). This project is referred to as an urban renaturalization program, utilizing riverbanks as a green belt. This project created green infrastructure in Seoul with the ability to prevent flooding even with predicted rainfall events occurring once every 200 years (Hambarde & Shinde, 2024; Kim & Jung, 2019).

- Riverbank Green Belt in Singapore

The Singapore government is implementing a riverbank naturalization program by placing vegetation elements to improve aesthetics, ecology, and hydrological function. Bishan-Ang Mo Kio Park is a 62-hectare urban park crossed by the Kallang River. This area is formed by a natural river with a flat bottom and green riverbanks. The presence of vegetation has increased urban biodiversity and supported a healthy ecosystem. The park also provides a habitat for birds and dragonflies. The development of this area demonstrates the government's attention to restoring the natural ecology of the city. Sustainable ecosystem development contributes to biodiversity and fosters a dynamic river ecosystem

Restoration of the Kham River in Aurangabad, India

The Kham River, which flows through the city of Chhatrapati Sambhajinagar (formerly Aurangabad) in India, was originally an important water source. However, over time and under the pressure of human activity, the river has experienced a decline in its ecological and social functions. The river's physical degradation is characterized by the decline of its water sources, leaving it little more than a ditch. Water pollution and severe degradation due to pollution and misuse have led to it often being mistaken for a ditch.



Figure 3. Past and Present Condition of Kham River in Aurangabad, India

Past photographs depict the river's condition in the 1800s. Current conditions, however, show a low water flow due to heavy sedimentation and waste disposal in 2018. Awareness of the need to restore this river is growing with data showing high levels of pollution and critical physical damage. (Karhade et al., 2020) explain that the river is severely polluted due to the accumulation of waste downstream. The water quality is also very low and does not meet the standards set for household use.

In the early 2020s, the city government developed a river restoration program encompassing in-situ bioremediation, waste management, bank stabilization, ecologically friendly public spaces, and community education. Within four to five years, the government has successfully demonstrated that Kham River restoration can be achieved by integrating scientific methods and policy. This program has generated complex benefits (ecological, economic, and social) for the city, characterized by improved environmental quality, reduced local flood risk, and strengthened community-river relationships.

- River Restoration in Yogyakarta

The development of green infrastructure in Yogyakarta is focused on three rivers, namely Winongo, Code, and Gajahwong. The local government has developed three programs to reactivate the ecological function of the river by facilitating the flow of water, making the river banks a green public space that can be enjoyed by the community and developing green elements to have water tourism attractions & open spaces of the city. The restoration of the Winongo River in Bantul is carried out through various efforts, such as garbage cleaning, normalization of river troughs to overcome silting, and arrangement of slum areas on the riverbanks. The goal is to restore the ecological function of the river, prevent flooding, and turn it into a more beautiful area and has the potential to become a tourist destination. Variations in the use of riverbanks are designed to accommodate the needs of settlements for green open space. (Davtalab et al., 2020; Şenik & Uzun, 2022).

Conclusion

Land Management in the riverbanks will be sustainable starting with a technical approach. Maintenance of infrastructures can be achieved with the participation of the community, supported by the use of facilities. However, the important thing is also the physical quality of the area that combines ecological and economic functions will encourage the entry of tourists to enjoy the natural beauty in urban areas. Thus, riverbanks can maintain a natural drainage system that is adaptive to climate change and contributes to social well-being.

Acknowledgment

The author would like to express sincere gratitude to the Faculty of Engineering, Universitas Negeri Makassar, for the support and academic environment that facilitated the completion of this study. Appreciation is also extended to all colleagues and reviewers whose insights and constructive feedback contributed to improving the quality of this article.

References

Bille, R. A., Jensen, K. E., & Buitenwerf, R. (2023). Global patterns in urban green space are strongly linked to human development and population density. *Urban Forestry & Urban Greening*, 86, 127980.

Ciommi, M., Chelli, F. M., Carlucci, M., & Salvati, L. (2018). Urban growth and demographic dynamics in southern Europe: Toward a new statistical approach to regional science. *Sustainability*, 10(8), 2765.

Das, S., & Sarkar, R. (2025). Role of Anthropogenic Activities on the Riverbank Instability: A Geospatial Analysis on Part of the Bhagirathi-Hugli River, India. In *Contemporary Social*
1st ICE3SHT 2025

- Physics: Decoding Social Behaviour with Advanced Geospatial Tools* (pp. 217–248). Springer.
- Davtalab, J., Deyhimi, S. P., Dessi, V., Hafezi, M. R., & Adib, M. (2020). The impact of green space structure on physiological equivalent temperature index in open space. *Urban Climate*, 31, 100574.
- de Manuel, B. F., Méndez-Fernández, L., Peña, L., & Ametzaga-Arregi, I. (2021). A new indicator of the effectiveness of urban green infrastructure based on ecosystem services assessment. *Basic and Applied Ecology*, 53, 12–25.
- Fang, X., Li, J., & Ma, Q. (2023). Integrating green infrastructure, ecosystem services and nature-based solutions for urban sustainability: A comprehensive literature review. *Sustainable Cities and Society*, 98, 104843.
- Hambarde, A., & Shinde, K. (2024). Tourism urbanisation in metropolitan fringe: insights from the tourist city of Lavasa in Pune, India. *Sustainability*, 16(2), 616.
- Harjanti, I. M., & Anggraini, P. (2020). Green Open Space Functions in Kauman Area, Semarang City, Indonesia. *Journal of Architectural Design and Urbanism*, 3(1), 1–9.
- Karhade, V. R., Kamble, A. L., Vangujare, S. B., Wadgaonkar, P. S., Gadekar, G. S., & Godihal, J. (2020). Environmental Impact Assessment of Anthropogenic Activities and Conceptual Restoration Strategy for Kham River in Aurangabad, India. *Current World Environment*.
- Kim, H., & Jung, Y. (2019). Is Cheonggyecheon sustainable? A systematic literature review of a stream restoration in Seoul, South Korea. *Sustainable Cities and Society*, 45, 59–69.
- Lee, D. K., & Song, Y. (2019). Urban green infrastructure and the ecological functions. *Landscape and Ecological Engineering*, 15(3), 241–243.
- Monteiro, R., Ferreira, J. C., & Antunes, P. (2020). Green infrastructure planning principles: An integrated literature review. *Land*, 9(12), 525.
- Pertiwi, N., & Lullulangi, M. (2018). Relation the Entrepreneurship Passion of Farmer and the Riverbank Management. *Journal of Entrepreneurship Education*, 21(4), 1–8.
- Profiroi, C. M., Bodislav, D. A., Burlacu, S., & Rădulescu, C. V. (2020). Challenges of sustainable urban development in the context of population growth. *European Journal of Sustainable Development*, 9(3), 51.
- Qiao, S., Huang, G., & Yeh, A. G.-O. (2022). Mobility as a Service and urban infrastructure: From concept to practice. *Transactions in Urban Data, Science, and Technology*, 1(1–2), 16–36.
- Şenik, B., & Uzun, O. (2022). A process approach to the open green space system planning. *Landscape and Ecological Engineering*, 18(2), 203–219.
- Sun, Y., & Cui, Y. (2018). Analyzing urban infrastructure economic benefit using an integrated approach. *Cities*, 79, 124–133.
- Wang, J., & Banzhaf, E. (2018). Towards a better understanding of Green Infrastructure: A critical review. *Ecological Indicators*, 85, 758–772.
- Wu, S.-S., Cheng, J., Lo, S.-M., Chen, C. C., & Bai, Y. (2021). Coordinating urban construction and district-level population density for balanced development: An explorative structural equation modeling analysis on Shanghai. *Journal of Cleaner Production*, 312, 127646.
- Ying, J., Zhang, X., Zhang, Y., & Bilan, S. (2022). Green infrastructure: Systematic literature review. *Economic Research-Ekonomska Istraživanja*, 35(1), 343–366.

Scope : Environment

Article ID : 108

ANALYZING KUMPARAN GREEN INITIATIVE: A MODEL OF DIGITAL ENVIRONMENTAL JOURNALISM

Muhammad Darisman*, Nadiroh, and Ananto Kusuma Seta

Post Graduate of Universitas Negeri Jakarta, Jakarta, Indonesia

E-mail: "muhammad.darisman@mhs.unj.ac.id

Abstract

This paper explores *Kumparan Green Initiative* as an emerging model of digital environmental journalism in Indonesia. The study examines how Kumparan integrates sustainability communication, storytelling, and audience participation in promoting the Sustainable Development Goals (SDGs). Using qualitative content analysis, this research reviews articles and campaigns published between 2024 and 2025, focusing on narrative techniques, issue framing, and public engagement. The results show that Kumparan initiative adopts a constructive and collaborative approach that enhances public understanding of environmental issues while inspiring behavioral change. This initiative contributes theoretically to the field of environmental communication and practically to the development of media-based sustainability education.

Keywords: Environmental journalism, digital media, Green Initiative, SDGs, sustainability communication

Introduction

The global media environment has shifted significantly in the digital age, influencing how people understand and respond to environmental issues. As audiences increasingly rely on online platforms for news consumption, digital journalism has become a vital space for communicating sustainability and climate-related topics (Anderson & Hansen, 2021; Doyle, 2020). In Indonesia, despite the rapid growth of online media, environmental coverage often remains limited, fragmented, and event-driven (Susanto, 2021). This challenge has encouraged several digital news organizations to develop specialized programs that merge environmental reporting with education and public engagement.

Kumparan Green Initiative emerged in 2024 as one of Indonesia's first integrated environmental journalism programs within a mainstream digital platform. It functions not only as a news channel but also as a collaborative campaign that connects communities, organizations, and the public in shared efforts to achieve sustainability goals. Similar initiatives worldwide emphasize how digital storytelling can strengthen environmental literacy and collective responsibility (Gherheş, 2025; Felleman, 2019). By examining this model, the study aims to understand how digital journalism in a developing country context can advance environmental awareness and action.

Environmental journalism serves as a bridge between scientific knowledge and the public sphere (Hansen, 2019). It does not merely describe ecological problems but seeks to motivate solutions and participation a perspective consistent with constructive journalism (McIntyre &

Gyldensted, 2018). This research therefore positions the Kumparan model within that theoretical framework, focusing on how narratives, audience engagement, and visual communication can contribute to the dissemination of sustainability values.

The guiding research question is: *How does Kumparan Green Initiative contribute to environmental awareness and SDG-based communication through digital journalism?*

Method

This research uses a qualitative content analysis approach (Mayring, 2021; Kuckartz & Rädiker, 2023) to analyze selected materials published on the *Kumparan Green Initiative* platform between 2024 and 2025. The data consist of news articles, video reports, and digital campaigns addressing topics such as waste management, green education, and sustainable consumption. Materials were selected based on their relevance to the SDGs, use of participatory communication, and narrative structure. Each item was examined for how it constructs meaning around environmental issues and how it involves audiences in sustainability discourse. The analysis combines manual interpretation and theory-guided categorization to connect communication patterns with broader principles of environmental journalism and public engagement.

Result and Discussion

The findings reveal that Kumparan Green Initiative employs a multidimensional communication strategy combining educational, participatory, and advocacy-oriented elements. Informative and educational articles often present environmental concepts using everyday language and relatable examples. Reports such as *“Budi Daya Maggot: Mendulang Cuan Sembari Mengurai Masalah Sampah Organik”* translate scientific ideas into practical knowledge, linking economic benefit with ecological responsibility. This style encourages public understanding and supports behavioral change aligned with SDG 12 (Responsible Consumption and Production).

Participatory storytelling is another major feature of the initiative. Stories like *“Sekolah Nol Sampah: Langkah Nyata Pendidikan Hijau di Bandung”* illustrate the collaboration among schools, communities, and local governments in implementing waste-reduction programs. Through this approach, Kumparan transforms complex environmental topics into human-centered narratives that foster empathy and engagement among readers. The combination of interviews, photographs, and visual storytelling allows audiences to identify with real actors driving sustainable change, reinforcing environmental citizenship (Borah & Salgado, 2022).

Advocacy and collaboration also play a central role in the Green Initiative’s content strategy. Campaigns such as *“Baliho Reborn”* demonstrate how post-election billboard waste can be recycled into eco-friendly products through community innovation. By highlighting the synergy between civic organizations and creative industries, Kumparan positions itself not only as a news outlet but also as a platform for environmental advocacy (Rahman, 2023; Nurhayati, 2022). This model represents a shift from traditional reporting toward participatory environmental communication, where audiences become part of the sustainability process rather than passive recipients of information.

Empirical evidence from Kumparan internal analytics (2024) shows that the Green Initiative channel achieved a 43 percent increase in readership and significant engagement through hashtags such as #HijaukanLangkahmu and #NoPlasticWeek. These campaigns encouraged users to document sustainable actions and share them through social media, creating a multiplier effect in environmental awareness. Such practices align with findings in digital communication studies, which highlight that participatory storytelling increases comprehension and action compared with purely informational formats (Pearce et al., 2019; Tandoc & Jenkins, 2021).

From a conceptual standpoint, Kumparan initiative integrates three dimensions of sustainable media practice. The first is editorial integration, where environmental issues are treated as part of the core media agenda rather than supplementary topics. The second dimension is technological innovation, utilizing data visualization, short videos, and social platforms to extend the reach of sustainability messages. The third is social collaboration, involving partnerships among journalists, researchers, policymakers, and communities. These three components demonstrate that Kumparan content model has evolved from conventional reporting into a collaborative process of meaning-making between media and society.

Globally, this aligns with the rise of constructive and “green” journalism, which promotes optimism, inclusivity, and solutions-oriented communication (León & Erviti, 2020). The Kumparan case reflects how such principles can be localized within an Indonesian context, combining scientific credibility with cultural storytelling traditions. Ultimately, this model confirms that digital journalism can serve as a catalyst for ecological awareness, community empowerment, and sustainable transformation

Conclusion

The Kumparan Green Initiative represents an innovative practice of environmental journalism in the digital era. Its integration of narrative, collaboration, and advocacy demonstrates how media organizations can advance sustainability communication while maintaining journalistic integrity. The initiative contributes to Indonesia’s progress toward the SDGs by fostering environmental literacy and mobilizing collective participation. The study suggests that similar models could be replicated in other Southeast Asian contexts to strengthen the regional ecosystem of digital environmental journalism. Future research may expand on audience reception analysis to assess long-term impacts on behavior and public policy discourse.

Acknowledgment

The author expresses sincere appreciation and deepest gratitude to Kumparan for its contribution and commitment in developing the Green Initiative as a model of environmental journalism content in Indonesia. This program has served as both an inspiration and an important reference in this study, particularly in understanding how digital media can play an active role in raising public awareness of sustainability issues and the Sustainable Development Goals (SDGs).

References

- Anderson, A., & Hansen, A. (2021). *Digital green journalism: Trends and challenges in environmental reporting*. Routledge.
- Anderson, A., Doyle, J., & Hansen, A. (2022). The rise of environmental narratives in the digital age. *Journal of Environmental Media*, 3(2), 115–129. https://doi.org/10.1386/jem_00045_1
- Borah, P., & Salgado, S. (2022). Engaging audiences through digital environmental campaigns. *Environmental Communication*, 16(4), 501–518. <https://doi.org/10.1080/17524032.2022.2043254>
- Dahlke, S. (2021). Constructive journalism and sustainability storytelling. *Journalism Studies*, 22(10), 1358–1375. <https://doi.org/10.1080/1461670X.2021.1941557>
- Doyle, J. (2020). *Environment and media* (2nd ed.). Routledge.
- Felleman, J. (2019). *Environmental journalism in the 21st century: Reporting, engaging, and advocating for sustainability*. Routledge.
- Gherheș, V. (2025). Analyzing climate change awareness campaigns: A bibliometric analysis. *Sustainability*, 17(9), 3979. <https://doi.org/10.3390/su17093979>
- Hansen, A. (2019). *Environmental communication and the public sphere* (5th ed.). Routledge.

- Kuckartz, U., & Rädiker, S. (2023). *Qualitative content analysis: Methods, practice and using software*. SAGE Publications.
- León, B., & Erviti, M. C. (2020). Communicating climate change through new media. *Science Communication*, 42(5), 623–647. <https://doi.org/10.1177/1075547020952137>
- Mayring, P. (2021). *Qualitative content analysis: A step-by-step guide*. SAGE Publications.
- McIntyre, K., & Gyldensted, C. (2018). Constructive journalism: An introduction and practical guide. *Journalism Practice*, 12(6), 678–693.
- McQuail, D. (2020). *McQuail's mass communication theory* (7th ed.). SAGE Publications.
- Nurhayati, R. (2022). Digital advocacy and eco-literacy: Online journalism practices in Indonesia. *Jurnal Komunikasi Nusantara*, 7(2), 88–101.
- Olausson, U. (2023). Environmental citizenship in the age of social media. *Environmental Communication*, 17(1), 75–91. <https://doi.org/10.1080/17524032.2022.2127801>
- Pearce, W., Brown, B., Nerlich, B., & Koteyko, N. (2019). Communicating climate change online: Challenges and opportunities. *WIREs Climate Change*, 10(5), e604. <https://doi.org/10.1002/wcc.604>
- Rahman, A. (2023). The impact of environmental news on green consumer behavior. *Journal of Environmental Communication Research*, 4(2), 144–158.
- Susanto, R. (2021). Environmental journalism in Indonesia: Progress and challenges. *Asian Journal of Communication*, 31(3), 235–250.
- Tandoc, E. C., & Jenkins, J. (2021). Audience engagement in environmental storytelling. *Journalism Studies*, 22(9), 1234–1251. <https://doi.org/10.1080/1461670X.2021.1913269>
- United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. <https://sdgs.un.org/2030agenda>

INNOVATIONS IN WASTE MANAGEMENT TOWARD A GREEN OFFICE AT THE JAKARTA PRESIDENTIAL PALACE

Y. Astuti, A. Husen, and G. D. Artanti

*Graduate School, Universitas Negeri Jakarta, Jl. Rawamangun Muka Kampus A UNJ, Ged. Bung
Hatta, Jakarta Timur 13220, Indonesia*

E-mail: *jeni.astuti@mhs.unj.ac.id

Abstract

Innovations in waste management at the Jakarta Presidential Palace align with President Prabowo's national agenda to accelerate comprehensive waste management by 2029. The government employs advanced technology, infrastructure upgrades, and public awareness efforts to manage waste from households and industries to final disposal. Key strategies include the adoption of Reduce, Reuse, Recycle (3R) principles, optimizing waste processing sites, and implementing waste-to-energy and refuse-derived fuel technologies. The Presidential Palace is designed as a green building, emphasizing energy efficiency, effective waste management, and superior environmental quality. The integration of technology optimizes energy, water use, and infrastructure to foster a sustainable green office environment. These innovations contribute to Indonesia's overarching goal of an environmentally friendly development model promoting circular economy and sustainability in government offices.

Keywords: Green, Waste, Palace, Environmental, innovation

Introduction

Waste management has become a crucial challenge in urban settings, including governmental environments that bear the responsibility of setting a model for sustainability. The Jakarta Presidential Palace, as the central office of government, requires a waste management system that is not only efficient but also environmentally friendly, aligned with the green office vision which emphasises the reduction of negative environmental impacts of waste. The Indonesian government has declared its commitment to resolving the national waste problem by 2029 through integrated strategies and policies (Hanif, 2025; Setkab, 2024). These strategies involve both upstream approaches, such as TPS-3R and Integrated Waste Processing Facilities (TPST), and downstream solutions, including Waste-to-Energy (WTE) and Refuse-Derived Fuel (RDF) (Hanif, 2025). Effective waste management necessitates the separation of organic and inorganic waste, followed by reuse and recycling practices. The implementation of composting technologies and waste bank (bank sampah) programs has been proven to enhance the efficiency of waste management systems (Haryati, 2024). At the national level, President Prabowo Subianto has underscored the acceleration of waste management through comprehensive upstream and downstream strategies, while the Minister of Home Affairs, Tito Karnavian (2025), highlighted the potential of organic waste treatment using decomposer larvae and waste-to-briquette conversion as both environmentally beneficial and economically valuable solutions.

Nevertheless, challenges persist. Reports show that only 39% of Indonesia's waste is currently processed through formal systems, with open dumping still common and recycling rates relatively low (The Investor, 2024). In this context, the Jakarta Presidential Palace offers a strategic case for piloting sustainable waste management innovations. Establishing a

comprehensive system that combines waste segregation, composting, waste banks, and policy innovations such as plastic reduction campaigns and continuous education may provide a replicable model of green office implementation for other government institutions.

Method

This study employed a descriptive qualitative approach with a case study design conducted within the Jakarta Presidential Palace complex over a period of four months. Data collection was carried out through multiple techniques, including semi-structured interviews with environmental managers, staff members, and relevant institutional representatives; participatory observation of on-site waste management practices; document analysis of existing policies and green office programs; and employee surveys aimed at assessing awareness and participation in waste management activities. The integration of these diverse data sources enabled a comprehensive understanding of the waste management system within the governmental context. To ensure the validity and reliability of findings, data were analysed thematically using a triangulation strategy that compared and corroborated evidence from interviews, observations, documentation, and survey results, thereby strengthening the credibility of the study's conclusions.

Result and Discussion

The waste management system implemented at the Jakarta Presidential Palace illustrates an integrative and multi-dimensional model that resonates with Indonesia's national goals for sustainable waste reduction. The system operates on the principle of source-based segregation, whereby organic and inorganic wastes are separated immediately at the point of generation. Organic waste is processed through in-house composting facilities, thereby reducing the load on municipal landfills while simultaneously producing compost that can be reused for on-site landscaping and greening initiatives. Inorganic waste, on the other hand, is managed through a waste bank scheme in collaboration with third-party recycling partners, creating opportunities for material recovery and contributing to a circular economy approach. These efforts are reinforced by institutional policies targeting the reduction of single-use plastics and supported by continuous employee education and awareness programs. The importance of such a system is consistent and that sustainable waste management requires systematic separation of organic and inorganic materials combined with resource recovery practices. Similarly, Haryati (2024) underlines the critical role of composting technologies and waste banks in enhancing efficiency and reducing dependency on conventional landfill disposal.

Beyond technological and procedural innovations, inter-agency collaboration has emerged as a crucial factor in ensuring the sustainability of the waste management system. The active synergy between the palace administration, the Jakarta Environmental Agency, and regional government-owned enterprises (BUMD) has significantly improved the utilization of government-provided facilities, such as TPS-3R and TPST, which serve as intermediaries in waste collection and processing. The integration of waste-to-energy (WTE) technology for residual waste represents an important downstream innovation, complementing upstream waste reduction efforts. Such integration reflects the government's strategic emphasis on combining reduction, reuse, recycling, and energy recovery within a unified waste management framework (Hanif, 2025; Agus Harimurti Yudhoyono, 2025). This collaborative governance approach highlights the institutional capacity of governmental organizations to mobilize resources, coordinate stakeholders, and ensure that sustainability targets are effectively translated into practice. The outcomes of these innovations are both quantitative and qualitative. Quantitatively, the system has succeeded in reducing final waste volumes by approximately 40–50% compared with previous practices, thereby decreasing the environmental burden on landfill facilities and contributing directly to national waste reduction targets. Qualitatively, continuous awareness campaigns and training programs have fostered a culture of environmental responsibility among employees,

demonstrating that human capital is equally vital as technological infrastructure in achieving sustainable outcomes.

These behavioral shifts affirm the significance of education and social participation as complementary pillars of waste governance, as supported by research showing that awareness-raising and community involvement are essential to long-term waste reduction (Setkab, 2024; The Investor, 2024). Moreover, the Presidential Palace case study demonstrates the symbolic role of government institutions in setting examples for environmental governance. By positioning itself as a model green office, the Presidential Palace underscores the importance of aligning operational practices with national sustainability goals and international discourses on sustainable development. This alignment not only supports the national target of comprehensive waste management by 2029 but also contributes to Indonesia's commitments under the Sustainable Development Goals (SDGs), particularly Goal 11 (Sustainable Cities and Communities) and Goal 12 (Responsible Consumption and Production). The integrative model of the Presidential Palace—combining technology, policy, and social participation—therefore serves as both a practical solution and a replicable framework for other government institutions aiming to implement sustainable waste management practices.

Conclusion

The findings of this study demonstrate that innovative waste management practices implemented at the Jakarta Presidential Palace provide a strong foundation for realizing the green office concept within governmental institutions. The integration of source-based segregation, the application of organic and inorganic waste treatment technologies, and the establishment of inter-agency collaboration have proven to be highly effective in reducing final waste volumes and promoting environmentally responsible behavior among employees. These results not only contribute to institutional sustainability but also align with Indonesia's national agenda of achieving comprehensive waste management by 2029. It is therefore recommended that this model be expanded and adapted across other government offices as part of a broader movement toward a waste-free Indonesia. Furthermore, the institutionalization of continuous environmental education and the reinforcement of supportive policies are essential to ensure long-term behavioral change, enhance institutional accountability, and strengthen the role of government entities as exemplars of sustainable environmental governance.

Acknowledgment

The authors would like to express their sincere gratitude to the Ministry of State Secretariat of the Republic of Indonesia, particularly the Presidential Secretariat, the Bureau of Palace Management, and the Environmental Management Division, for their valuable support and collaboration in this study. Special appreciation is also extended to colleagues from the Subdivision of Environmental Arrangement and Maintenance, as well as to the sanitation and garden maintenance staff, whose dedication and contributions were essential to the successful completion of this research.

References

- Aprilia, A., et al. (2021). Waste management in Indonesia and Jakarta: Challenges and innovations. ASEF.
- Asian Development Bank. (2023). Sustainable waste management in Asia-Pacific government buildings. <https://www.adb.org/publications/sustainable-waste-management-asia-pacific>
- Asian Institute of Technology. (2023). Behavioral change in office environmental practices. <https://www.ait.ac.th/publication/behavioral-change-office-environment>
- Basel Convention Secretariat. (2023). Guidelines on plastic waste reduction in government facilities. <https://www.basel.int/PlasticWasteGuidelines>

- C40 Cities. (2022). Hanoi's green office environmental management system. <https://www.c40.org/case-studies/green-office-hanoi>
- Energy Research Centre Netherlands. (2023). Refuse-derived fuel developments and policies. <https://www.ecn.nl/refuse-derived-fuel>
- Food and Agriculture Organization. (2024). Composting technologies for organic waste management. <http://www.fao.org/composting-technology>
- Global Green Growth Institute. (2023). Green office initiatives in Southeast Asia. <https://gggi.org/publications/green-office-southeast-asia>
- Haryati, D. (2024). Inovasi teknologi komposting dan bank sampah dalam mendukung pengelolaan lingkungan berkelanjutan. Universitas Terbuka Press.
- ICLEI. (2024). Local government innovations in waste governance. <https://iclei.org/waste-governance-innovations>
- International Energy Agency. (2025). Technologies for waste-to-energy conversion. <https://www.iea.org/reports/waste-to-energy-technologies>
- IEA Bioenergy Task 36. (2025). Environmental impacts of waste management strategies: Ireland & US case studies.
- International Labour Organization. (2023). Environmental education and employee engagement. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_123456.pdf
- International Renewable Energy Agency. (2024). Role of waste-to-energy in sustainable cities. <https://www.irena.org/publications/waste-to-energy>
- International Solid Waste Association. (2025). Best practices in waste segregation and composting. <https://www.iswa.org/best-practices-waste>
- Jorge-Ortiz, A., Braulio-Gonzalo, M., & Bovea, M. D. (2023). Exploring how waste management is being approached in green building rating systems: A case study. *Waste Management & Research*, 41(6). <https://doi.org/10.1177/0734242X221143952>
- Karnavian, T. (2025). Pengelolaan sampah organik melalui teknologi inovatif di Indonesia. Kementerian Dalam Negeri, Republik Indonesia.
- Penerapan Green Office pada Kementerian Kesehatan Republik Indonesia. (2022). *Jurnal Utilitas*, 2(1), 64–71. <https://doi.org/10.22236/utilitas.v2i1.4560>
- Sekretariat Kabinet. (2024, December 13). President Prabowo calls for accelerated national waste management by 2029. Cabinet Secretariat of the Republic of Indonesia. <https://setkab.go.id/en/president-prabowo-calls-for-accelerated-national-waste-management-by-2029/>
- Stockholm Environment Institute. (2023). Enhancing waste sorting and recycling practices. <https://www.sei.org/publications/waste-sorting-recycling>
- Sustainable Campus Through Organic Waste Management. (2023). *Journal of Sustainability Perspectives*. <https://ejournal2.undip.ac.id/index.php/jsp/article/view/21647>
- The Investor. (2024, October 14). Indonesia targets 100% waste management by 2029. <https://theinvestor.vn/indonesia-targets-100-waste-management-by-2029-d14834.html>
- Waste Disposal Efforts and Policies in BPSDM Kemendagri Jakarta. (2024). *Jurnal Manajemen Transportasi dan Logistik UNTAN*. <https://jurnal.untan.ac.id/index.php/jmtluntan/article/view/74724/0>
- Yudhoyono, A. H. (2025). Strategi nasional percepatan pengelolaan sampah melalui kolaborasi lintas sektor. Pemerintah Republik Indonesia.
- Zen, I. S. (2016). A case study of green office initiatives in Universiti. *Journal of Cleaner Production*, 135, 1257–1263. <https://doi.org/10.1016/j.jclepro.2016.06.063>

BUILDING COMMUNITY RESILIENCE VIA SOCIAL ECOLOGY IN SUSTAINABLE EDUCATION TO SUPPORT THE SUSTAINABLE DEVELOPMENT GOALS

Rihlah Nur Aulia^{1*} and Anneke Stamer²

¹*Postgraduate school, Jakarta State University, Jakarta, Indonesia*

²*Leipzig University, Leipzig, Germany*

E-mail: *rihlah-nuraulia@unj.ac.id

Abstract

This research investigates the incorporation of a social ecology framework within the realm of sustainable education as a tactical methodology for enhancing community resilience and promoting the Sustainable Development Goals (SDGs), with a specific emphasis on SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities). Employing a systematic literature review per the PRISMA guidelines, the study amalgamates insights derived from Scopus-indexed publications spanning various disciplines such as environmental education, transformative learning, and community development. The findings indicate that resilience is cultivated through the intricate interactions among individuals, communities, and their ecological contexts. Education predicated upon social ecology promotes ecological literacy, adaptive capabilities, and social solidarity. A conceptual framework is introduced to synchronize educational methodologies with social-ecological tenets and SDG objectives. The research concludes that integrating social ecology into educational frameworks is pivotal for nurturing empowered and sustainable communities; however, effective implementation necessitates institutional backing, inclusive pedagogical approaches, and collaborative engagement among multiple stakeholders.

Keywords: community resilience, social ecology, sustainable education, SDGs, transformative learning

Introduction

The imperative to cultivate resilient communities has escalated in response to global adversities such as climate change, rapid urbanization, and social inequities (Kisinger & Matsui, 2021). These adversities are not solely environmental or economic, but are profoundly intertwined with educational and social infrastructures (Carmen et al., 2022). The Sustainable Development Goals (SDGs), ratified by the United Nations in 2015, furnish a holistic framework to tackle these multidimensional challenges. Among the 17 objectives, SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities) hold particular significance within the realm of community resilience and sustainable education (J. Zhang et al., 2025). SDG 4 emphasizes inclusive and equitable quality education and lifelong learning opportunities for all (Pd Purwadhi, 2019). It recognizes education as a transformative tool to empower individuals and communities to make informed decisions, adapt to change, and participate actively in sustainable development (Nurova, 2023). Meanwhile, SDG 11 calls for making cities and human settlements inclusive, safe, resilient, and sustainable highlighting the need for community based strategies that integrate

environmental, social, and cultural dimensions(Ratliff et al., 2017). In this context, the social ecology perspective offers a powerful lens to understand and enhance community resilience (Kioupi & Voulvoulis, 2022). Social ecology views human communities as embedded within broader ecological systems, where resilience emerges from the dynamic interplay between individuals, institutions, and their environment(Brooks et al., 2016). This perspective aligns with the principles of Education for Sustainable Development (ESD) (Tafese & Kopp, 2025), which promotes critical thinking, participatory learning, and local engagement to foster sustainability(Smith et al., 2024). Despite the growing recognition of the importance of resilience and sustainability, many educational systems remain fragmented and disconnected from local realities(Brooks et al., 2016). There is a pressing need to reorient education toward sustainability by embedding social-ecological thinking into curricula, pedagogy, and community engagement (Boehnert et al., 2022)(Nurova, 2023).

Method

This study employs an exploratory qualitative approach using a Systematic Literature Review (SLR) guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol(Tedja et al., 2024). The primary objective of this methodology is to identify, evaluate, and synthesize scholarly literature relevant to integrating social ecology perspectives in sustainable education and its contribution to building community resilience and achieving the Sustainable Development Goals (SDGs)(Faisal M. Jasin, 2023). Research Design The SLR method was chosen to understand theoretical and empirical developments across disciplines comprehensively. This approach enables the researcher to identify trends and gaps, construct a relevant conceptual framework, and present a narrative synthesis of diverse studies.

Result and Discussion

Overview of Literature Findings

From the systematic literature review, 42 Scopus-indexed articles were selected after applying inclusion and exclusion criteria. These articles span diverse geographical contexts, including Southeast Asia, Sub-Saharan Africa, and Latin America, and cover themes such as social-ecological resilience, transformative learning, and community-based education. The synthesis revealed three dominant thematic clusters: **1) Social Ecology and Community Resilience.** **2) Sustainable Education and SDGs Integration.** **3) Transformative Learning and Local Empowerment**

Social Ecology as a Framework for Resilience

Social ecology emphasizes the interdependence between human communities and their ecological environments(Davids et al., 2021) (Ungar, 2011; Cosens, 2021). Studies show that communities with strong social networks, ecological literacy, and participatory governance are more resilient to climate-related shocks and socio-economic disruptions(Szczepankiewicz et al., 2021; Xue et al., 2021)For example, Zhang et al.(Zhang & Zhang, 2022) proposed a reconciled framework that integrates resilience and sustainability, highlighting feedback loops between education, environment, and community agency(Walker, B., and Salt, 2006). This aligns with SDG 11, which promotes inclusive and sustainable urban development through community participation and ecological integration(Tampi et al., 2018). Sustainable Education as a Driver of SDGs. Education for Sustainable Development (ESD) is central to achieving SDG 4. It fosters critical thinking, problem-solving, and active citizenship. The reviewed literature indicates that when education incorporates local ecological knowledge and social context, it becomes a powerful tool for resilience-building. Tafese & Kopp (2025) found that schools implementing ESD curricula reported higher levels of student engagement in community sustainability projects. Similarly,

Kioupi & Voulvoulis (2022) demonstrated that integrating SDGs into classroom activities enhances students' understanding of global challenges and their role in addressing them. However, challenges remain: Fragmentation between formal education and community realities, Lack of teacher training in sustainability pedagogy, and limited institutional support for interdisciplinary approaches(Yasida, 2020).

Transformative Learning and Local Empowerment

As applied in community education, transformative learning theory emphasizes reflection, dialogue, and experiential learning. Ruiz-Malléna et al. (2022) documented how environmental education programs in urban slums increased civic engagement and ecological stewardship among youth. In Indonesia(Jasin et al., 2024), community-based initiatives such as ecopesantren and green villages have shown promising results in integrating religious, cultural, and ecological values into education (Nugraha et al., 2023). These models demonstrate that resilience is cultivated through knowledge, identity, values, and collective action.

Proposed Integration Model.

Based on the synthesis, the following model is proposed to integrate social ecology into sustainable education:

Table 1. the proposed to integrated social ecology into sustainable education

Component	Social Ecology Principle	Educational Strategy	SDG Alignment
Human–Nature Relationship	Ecological interdependence	Place-based learning	SDG 4, SDG 13
Community Networks	Social capital	Collaborative projects	SDG 11, SDG 16
Adaptive Capacity	Feedback and learning loops	Reflective pedagogy	SDG 4, SDG 17
Equity & Inclusion	Cultural relevance	Participatory curriculum	SDG 5, SDG 10

This model encourages educators and policymakers to design learning environments responsive to local ecological and social contexts, fostering resilience through education.

Conclusion

This study highlights the critical role of integrating a social ecology perspective into sustainable education as a strategic pathway to enhance community resilience and contribute meaningfully to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities). The systematic literature review reveals that resilience is not a static attribute but an emergent property of dynamic interactions between individuals, communities, and their ecological environments. Education becomes a transformative force that fosters ecological literacy, adaptive capacity, and social cohesion when designed to reflect these interdependencies. The proposed integration model offers a conceptual framework that aligns educational strategies with ecological and social dimensions.

Acknowledgment

The author would like to express sincere gratitude to all scholars whose work contributed to the foundation of this study through the systematic literature review. Special appreciation is extended

to the academic community at Universitas Negeri Jakarta and Leipzig University for their continuous support and intellectual engagement throughout the research process.

References

- Aulia, R. N. (n.d.). *Social Reconstruction Curriculum In Facing 21st Century Learning*. <https://isolec.um.ac.id/proceeding/index.php/issn/article/view/85>
- Boehnert, J., Sinclair, M., & Dewberry, E. (2022). Sustainable and Responsible Design Education: Tensions in Transitions. *Sustainability (Switzerland)*, 14(11). <https://doi.org/10.3390/su14116397>
- Brooks, S., Metcalf, E. C., Zedalis, M., Gosz, J., Kliskey, A., & Alessa, L. (2016). *Title: A social-ecological systems approach for environmental management Author names: Arika Virapongse* a A social-ecological systems approach for environmental management*.
- Carmen, E., Fazey, I., Ross, H., Bedinger, M., Smith, F. M., Prager, K., McClymont, K., & Morrison, D. (2022). Building community resilience in a context of climate change: The role of social capital. *Ambio*, 51(6), 1371–1387. <https://doi.org/10.1007/s13280-021-01678-9>
- Davids, R., Rouget, M., Burger, M., Mahood, K., Dithale, N., & Slotow, R. (2021). Civic ecology uplifts low-income communities, improves ecosystem services and well-being, and strengthens social cohesion. *Sustainability (Switzerland)*, 13(3). <https://doi.org/10.3390/su13031300>
- Faisal M. Jasin. (2023). *RESILIENSI MASYARAKAT RENTAN BENCANA BANTARAN SUNGAI CILIWUNG* (1st ed.). Pena Persada.
- Jasin, F. M., Aulia, R. N., Anwar, H., Aryansyah, A. P., Lingkungan, T., Sosial, F. I., & Jakarta, U. N. (2024). *MENUJU SEKOLAH SEHAT BERBUDAYA LINGKUNGAN SMPN. 2024*, 94–101.
- Kioui, V., & Voulvoulis, N. (2022). Education for Sustainable Development as the Catalyst for Local Transitions Toward the Sustainable Development Goals. *Frontiers in Sustainability*, 3. <https://doi.org/10.3389/frsus.2022.889904>
- Kisinger, C., & Matsui, K. (2021). Responding to climate-induced displacement in bangladesh: A governance perspective. *Sustainability (Switzerland)*, 13(14), 1–12. <https://doi.org/10.3390/su13147788>
- Nurova, O. (2023). Ecological education as a basis for social sustainable development. *E3S Web of Conferences*, 460. <https://doi.org/10.1051/e3sconf/202346005011>
- Pd Purwadhi, M. (2019). The role of education management, learning teaching and institutional climate on quality of education: Evidence from indonesia. *Management Science Letters*, 9(9), 1507–1518. <https://doi.org/10.5267/j.msl.2019.5.002>
- Ratliff, K. A., Howell, J. L., & Redford, L. (2017). Attitudes toward the prototypical environmentalist predict environmentally friendly behavior. *Journal of Environmental Psychology*, 51, 132–140. <https://doi.org/10.1016/j.jenvp.2017.03.009>
- Smith, W. C., Ehren, M. C. M., & Grek, S. (2024). Global governance of education: The Sustainable Development Goals as a product and mechanism? In *International Review of Education* (Vol. 70, Issue 4, pp. 531–545). Springer Science and Business Media B.V. <https://doi.org/10.1007/s11159-024-10108-3>
- Szczepankiewicz, E. I., Fazlagić, J., & Loopesko, W. (2021). A conceptual model for developing climate education in sustainability management education system. *Sustainability (Switzerland)*, 13(3), 1–26. <https://doi.org/10.3390/su13031241>
- Tafese, M. B., & Kopp, E. (2025). Education for sustainable development: analyzing research trends in higher education for sustainable development goals through bibliometric analysis. In *Discover Sustainability* (Vol. 6, Issue 1). Springer Nature. <https://doi.org/10.1007/s43621-024-00711-7>
- Tampi, D. M., Sumabrata, J., Zubair, A., & Kinan, N. H. (2018). A Group in Urban: The Social

Capital of Ciliwung Depok Community (KCD). *IOP Conference Series: Earth and Environmental Science*, 129(1). <https://doi.org/10.1088/1755-1315/129/1/012028>

Tedja, B., Al Musadieq, M., Kusumawati, A., & Yulianto, E. (2024). Systematic literature review using PRISMA: exploring the influence of service quality and perceived value on satisfaction and intention to continue relationship. *Future Business Journal*, 10(1). <https://doi.org/10.1186/s43093-024-00326-4>

Walker, B. and Salt, D. (2006). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press.

Xue, K., Guo, S., Liu, Y., Liu, S., & Xu, D. (2021). Social networks, trust, and disaster-risk perceptions of rural residents in a multi-disaster environment: Evidence from Sichuan, China. *International Journal of Environmental Research and Public Health*, 18(4), 1–25. <https://doi.org/10.3390/ijerph18042106>

Yasida, K. S. (2020). Eco-Pedagogy Eco-Pedagogi. *Historika Journal*, 23(1), 70–79.

Zhang, Y., & Zhang, H. (2022). The Development of Intelligent Education and Teachers' Professional Informatization Led by an Intelligent Ubiquitous Network. *Computational Intelligence and Neuroscience*, 2022, 3997080. <https://doi.org/10.1155/2022/3997080>

APPLICATION OF INPUT-OUTPUT LEONTIEF ANALYSIS FOR WATER TARIFF CALCULATION IN INTEGRATED WATER CYCLE MANAGEMENT

Martin Darmasetiawan^{1*} and Teddy Tedjakusuma²

¹Universitas Pelita Bangsa, Kabupaten Bekasi, Indonesia

²Institut Teknologi Bandung, Bandung, Indonesia

E-mail: *martin.darmasetiawan@pelitabangsa.ac.id

Abstract

Water tariffs are traditionally determined based only on the operational and maintenance costs of Water Treatment Plants (WTPs), often overlooking the interconnected hydrological and economic processes that sustain urban water systems. This study applies the Leontief Input– Output (I–O) model to capture the interdependence among key components of the artificial water cycle, including rainfall capture, catchment areas, reservoirs or lakes, WTPs, and Wastewater Treatment Plants (WWTPs). By modeling each subsystem as an economic sector, the Leontief framework quantifies both direct and indirect costs required to deliver one cubic meter of treated water. Approximately 4.5 m³ of rainfall are needed to produce 1 m³ of treated water, with indirect costs representing around 64% the expenditure. Full-cost recovery tariff is Rp 7,168/m³, encompassing all upstream and downstream processes. This approach provides method for water pricing, supporting policymakers in designing sustainable, closed-loop water management systems that reflect true economic and environmental costs.

Keywords: water tariff, input–output, Leontief, OPEX, CAPEX, water recycling, WTP, WWTP.

Introduction

Water tariffs are often determined based solely on the operational and maintenance costs of Water Treatment Plants (WTPs), overlooking the broader hydrological and economic interconnections vital for sustainable, closed-loop water management. In modern systems, multiple components—such as stormwater control, reservoirs, and Wastewater Treatment Plants (WWTPs)—jointly regulate water availability and enable reuse, forming an artificial water cycle that includes rainfall capture, consumption, wastewater collection, and recycling.

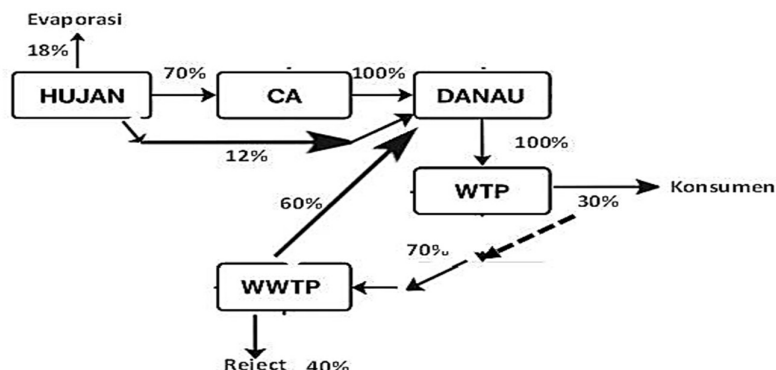


Figure 1. The Artificial Water Cycle

The complexity of these interactions requires an analytical framework capable of quantifying both technical and economic interdependencies among subsystems. The Leontief Input–Output (I–O) model, originally developed for macroeconomic analysis, provides such a framework by tracing cost flows and inter-sectoral dependencies. Applied to water management, it enables the calculation of comprehensive and equitable tariffs that reflect the true cost of sustaining the entire water cycle—covering not only direct treatment expenses but also long-term investments in system integration and resilience.

Methodology

The Leontief Input–Output Model

The Leontief model describes the interdependence between sectors or components in a technical system. The fundamental equation is:

$$x = Ax + d \quad (1)$$

where:

x = vector of total output (m³ or Rp),

A = matrix of input coefficients,

d = vector of final demand (e.g., consumer water use).

Rearranging gives:

$$x = (I - A)^{-1}d \quad (2)$$

The matrix $(I - A)^{-1}$, known as the Leontief Inverse, represents the total (direct + indirect) required to meet one unit of final demand.

The matrix representation below follows the conventional Leontief formulation but is customized here to represent the water cycle network among rainfall, catchment, reservoir, WTP, and WWTP seen in Table 1.

Table 1. Components of the Artificial Water Cycle

No	Component	Symbol	Description
1	Rainfall	CA	Absorption of rainfall within the catchment area
2	Reservoir/Lake	–	Storage of raw water before treatment
3	WTP	–	Clean water processing
4	WWTP	–	Wastewater treatment
5	Recycling	–	Reuse of treated wastewater

These components are interdependent; outputs from one process serve as inputs to others. For example, treated effluent from the WWTP can replenish reservoirs or supplement WTP inflow.

Application to Water Tariff Estimation

In this study, each water subsystem is treated as an “economic sector.” The Leontief model enables computation of total (direct and indirect) operational expenditures (OPEX) and capital amortization (CAPEX) for the entire artificial hydrological cycle. Thus, the comprehensive cost of producing 1 m³ of clean water includes all upstream and downstream processes—rainfall capture, storage, treatment, and recycling.

Results and Discussion

Model Overview

The system comprises five components: Rainfall (X_1), Catchment Area (X_2), Reservoir/Lake (X_3), Water Treatment Plant (WTP, X_4), and Wastewater Treatment Plant (WWTP, X_5).

The model’s relationships are summarized in the input coefficient matrix A :

$$A = \begin{bmatrix} 0 & 0.70 & 0.12 & 0 & 0.18 \\ 0 & 0 & 1.00 & 0 & 0 \\ 0 & 0 & 0 & 1.00 & 0 \\ 0 & 0 & 0 & 0 & 0.70 \\ 0 & 0 & 0.60 & 0 & 0 \end{bmatrix} \quad (3)$$

This indicates, for example, that 70 % of rainfall becomes input to the catchment area, while 100 % of stored water is processed at the WTP.

Leontief Calculation

Using

$$x = (I - A)^{-1}d \quad (4)$$

with the demand vector

$$d = [0.82, 1.00, 1.00, 0.70, 0.60]^T,$$

the Leontief inverse gives the total output for each component (Table 2).

Table 2. Output for Each Component

Component	Symbol	Total Output x_i (m ³)	Interpretation
Rainfall	X ₁	4.50	Rainfall required to sustain 1 m ³ of treated water
Catchment	X ₂	4.66	Flow through catchment
Reservoir/Lake	X ₃	3.66	Stored volume
WTP	X ₄	2.66	Treated water volume
WWTP	X ₅	2.79	Treated wastewater for reuse

The model indicates that to deliver 1 m³ of treated water, approximately 4.5 m³ of rainfall must be captured. This amplification reflects cumulative losses due to evaporation, infiltration inefficiency, and process wastage throughout the system. The balance among outputs shows that internal recycling reduces total water demand from natural sources, illustrating the importance of WWTP integration in achieving water sustainability.

Estimation of OPEX and CAPEX

Table 3. The cost structure of each subsystem is summarized

Component	OPEX (Rp/m ³)	CAPEX (Rp/m ³)	Total (Rp/m ³)	Description
Catchment	100	70	170	Maintenance of infiltration facilities
Lake/Reservoir	50	10	60	Sediment and aeration management
WTP	2,500	500	3,000	Clean water treatment
WWTP	3,000	600	3,600	Wastewater treatment and recycling

3.4 Comprehensive Water Tariff

By integrating technical coefficients and cost data, the total system expenditure was determined using the equation:

$$T = i = 1nx_i(OPEX_i + CAPEX_i) \times WTP \quad (5)$$

Table 4. Presents the derived total cost contributions of each component.

Table 4. Component Cost

Component	Total Cost (IDR/m ³)	x_i	$x_i \times \text{Cost (IDR)}$
Catchment	170	4.66	791
Lake	60	3.66	219
WTP	3,000	2.66	7,966
WWTP	3,600	2.79	10,055
Component	Total Cost (Rp/m ³)	x_i	$x_i \times \text{Cost (Rp)}$
Total	–	–	19,031

Tariff=19,031/2.66=Rp 7,168/m³

Dividing the total cumulative cost (Rp 19,031) by the WTP output (2.66 m³) yields a **full-cost recovery tariff of Rp 7,168/m³**. This value represents the integrated cost of producing and recycling water within a closed-loop system, far more comprehensive than conventional tariffs based solely on WTP operation.

Table 5. Direct and Indirect Cost Analysis

Component	Direct (Rp/m ³)	Indirect (Rp/m ³)	Total (Rp/m ³)
Catchment	170	621	791
Lake	60	159	219
WTP	3,000	4,966	7,966
WWTP	3,600	6,455	10,055
Total	6,830	12,201	19,031

See;-Table 4

Table 6. Tariff Share

Category	Share (%)	Tariff Equivalent (Rp/m ³)
Direct	36	2,572
Indirect	64	4,595
Total Tariff	100	7,168

Indirect costs account for roughly 60–65 % of total system expenditure, illustrating the importance of maintenance, monitoring, and system integration in overall tariff design.

Model Evaluation

The Leontief I–O approach offers several advantages:

- **Systemic Consistency:** All inter-component dependencies are quantitatively represented.
- **Cost Transparency:** Each subsystem's contribution to the total tariff can be clearly traced.
- **Policy Simulation:** The model allows analysis of recycling efficiency or CAPEX/OPEX sensitivity under different scenarios.

Limitations include the assumption of fixed technical coefficients, which may not capture seasonal variability, and the exclusion of non-monetized environmental externalities such as land degradation or pollution residuals. Future work should integrate dynamic coefficients and life-cycle cost elements for greater realism.

Conclusion

The Leontief Input–Output model provides a structured, quantitative framework for determining full-cost water tariffs in closed-loop systems. By accounting for all direct and indirect interactions across rainfall capture, storage, treatment, and reuse, the method ensures both cost transparency and equitable burden sharing. The derived tariff of approximately Rp 7,168/m³ reflects the true cost of sustaining a resilient, circular water system.

This modeling approach can guide policymakers and planners in developing efficiency based, sustainability-oriented water pricing strategies aligned with long-term resource management goals.

Acknowledgment

The authors would like to express their sincere gratitude to Universitas Pelita Bangsa and Institut Teknologi Bandung for the academic support and collaboration that enabled the completion of this study. Appreciation is also extended to colleagues and reviewers whose valuable insights and constructive suggestions have contributed to improving the quality and clarity of this paper.

References

- Mohan, G., Chapagain, S. K., Fukushi, K., Papong, S., I. M. Sudarma, A. B. Rimba, & Osawa, T. (2021). *An extended Input–Output framework for evaluating industrial sectors and provincial-level water consumption in Indonesia*. *Water Resources and Industry*, 25, 100141. <https://doi.org/10.1016/j.wri.2021.100141> nstda.or.th+2collections.unu.edu+2
- Fitriani, H., Kurniawan, M. A., & Hadinata, F. (2023). *Analysis of tariff adjustment for clean water usage*. *Scientific Review Engineering and Environmental Sciences (SREES)*, 32(2), 155-174. <https://doi.org/10.22630/srees.4790> srees.sggw.edu.pl
- Marleni, N. N., & Raspati, G. S. (2020). *A Critical Review of Wastewater Resource Recovery Implementation in Indonesia*. *Civil Engineering Forum*, 6(1). <https://doi.org/10.22146/jcef.52755> Jurnal Universitas Gadjah Mada
- Alabi, O., et al. (2019). *Physical Water Use and Water Sector Activity in Environmental Input–Output Analysis*. Regional Science Policy & Practice. rrs.scholasticahq.com
- Ke, W., Sha, J., Yan, J., Zhang, G., & Wu, R. (2016). *A Multi-Objective Input–Output Linear Model for Water Supply, Economic Growth and Environmental Planning in Resource-Based Cities*. *Sustainability*, 8(2), 160. MDPI
- Camilla, S., et al. (2020). *Defining Sustainability in an Input–Output Model: An Application to Spanish Water Use*. *Water*, 13(1), 1. MDPI
- Gardels, D., Stansbury, J., Killion, S., Zhang, T., Neal, J., Alahmad, M., Berryman, C., & Lau, S. (2011). *Economic Input–Output Life Cycle Assessment of Water Reuse Strategies in Residential Buildings*. Conference Proceeding. repository.lsu.edu
- Piubello Orsini, L., Leardini, C., Danesi, L., Guerrini, A., & Frison, N. (2023). *Circular Economy in the Water and Wastewater Sector: Tariff Impact and Financial Performance of SMARTechs*. *Journal of Urban Policy & Research*. IDEAS/RePEc
- Mohan, G., et al. (2021). *Spatiotemporal Evolution and Driving Mechanisms of Water Footprint with Input-Output Paradigm: A Case Study of China*. *Water*, 14(15), 2373. MDPI
- Steenge, A. E. (2009). “Social Cost in the Leontief Environmental Model: Rules and Limits to Policy”. In E. Dietzenbacher & M. L. Lahr (Eds.), *Wassily Leontief and Input-Output Economics* (pp. 367-386). Cambridge University Press. Cambridge University Press & Assessment
- Lenzen, M. (2017). *Environmental Input–Output Analysis and Water Use: A Review of Methods and Applications*. (Review Article)

- Bowen, A., & Hepburn, C. (2017). *Green Growth, Input–Output and Water Resource Accounting*. Journal of Environmental Economics & Policy.
- Fitzsimmons, M. J., & Loïc, M. (2018). *Water Tariff Formulation in Reuse Systems: A Comparative Study of Industrial Parks*. Water Policy.
- Hernandez-Sancho, F., & Castellet-Viciano, L. (2018). *Cost Recovery Mechanisms for Reclaimed Water Tariffs in Mediterranean Countries*. Water Supply.
- Zhang, Y., & Huang, G. H. (2019). *Input–Output-Based Decision Support for Industrial Water Reuse and Tariff-Setting*. Journal of Cleaner Production.
- Meng, Q., & Hu, J. (2020). *Embedding Life-Cycle Costing in Input–Output Analysis: Application for Water Infrastructure Investment*. Water Research.
- Li, S., & Xu, Z. (2020). *Tariff Design for Urban Water Supply Under Reuse and Recycling Scenarios: An Input–Output Approach*. Resources, Conservation & Recycling.
- Pereira, L. S., & Martinez, E. (2021). *Economic Instruments and Input–Output Modeling for Combined Water and Wastewater Tariffs in Industrial Zones*. Water Economics & Policy.
- Zhao, X., & Wang, T. (2022). *Dynamic Input–Output Modeling for Urban Water Tariff Adjustments Considering Climate Impacts*. Journal of Hydrology.
- Handayani, R., Putri, G. L., Felaza, E., & Tjahjono, T. (2017). *Water Recycling Opportunity in the Business Sectors of Greater Jakarta, Indonesia*. *International Journal of Technology*, 8(6), 1031-1039. <https://doi.org/10.14716/ijtech.v8i6.743> International Journal of Technology

THE USE OF NAPIER GRASS (*PENNISETUM PURPUREUM* cv. MOTT) FOR RIVERBANK PROTECTION

Asnita Virlayani^{1*}, Nurlita Pertiwi², and Mithen Lullulangi²

¹Water Resources Engineering Study Program, Faculty of Engineering, Universitas Muhammadiyah Makassar, Makassar, Indonesia

²Population and Environmental Education, Universitas Negeri Makassar, Makassar, Indonesia

E-mail: *asnita.virlayani@unismuh.ac.id

Abstract

The riverbank protection requires ecological approaches that utilize local vegetation with strong adaptability. This study aims to analyze the effectiveness of Napier grass (*Pennisetum purpureum* cv. Mott) in strengthening soil structure and reducing erosion along riverbanks. The research method involved planting Napier grass at several critical points along the riverbank, followed by observations of the reduction in erosion rates compared to control areas with and without vegetation through a field experiment. The results showed that Napier grass develops a dense and strong fibrous root system, which significantly increases soil cohesion and reduces the risk of riverbank collapse. Additionally, its vegetative cover serves as an effective ground shield against raindrop impact, thereby minimizing surface soil erosion. Therefore, the use of *Pennisetum purpureum* cv. Mott is a sustainable and environmentally friendly alternative for riverbank protection.

Keywords: Napier Grass, Erosion, Riverbank, Soil Conservation, Vegetative

Introduction

Riverbank erosion is one of the most serious environmental problems that threatens both ecosystems and human settlements, particularly in regions with high rainfall intensity and unstable soil structures. (Islam and Guchhait 2024)(Li et al. 2023) In Indonesia, numerous rivers are experiencing degradation of their riverbanks due to deforestation, poor land management, and increased water discharge during the rainy season (Kelley and Prabowo 2019). The problem addressed in this research is the effectiveness of Napier grass in minimizing runoff and stabilizing soil on riverbanks under varying slope conditions and rainfall intensities. The study is expected to provide scientific data that can support the use of biological methods in riverbank management. Furthermore, it offers potential benefits for local governments and communities seeking cost-effective and sustainable solutions for riverbank conservation.

The use of vegetation for soil and water conservation, particularly in riverbank stabilization, has become a sustainable and environmentally friendly alternative to conventional engineering methods. Among various plant species, Napier grass (*Pennisetum purpureum* cv. Mott) has shown promising characteristics in reducing surface runoff, increasing soil infiltration, and binding soil particles with its dense root system(Kang and Tazoe 2024). Its rapid growth, high biomass production, and adaptability to diverse soil conditions make it an effective species for riverbank protection in tropical environments. The use of Napier grass (*Pennisetum purpureum* cv. Mott) for riverbank protection has emerged as a sustainable and eco-friendly solution to

mitigate soil erosion and stabilize riverbanks, particularly in tropical regions like Indonesia. Napier grass is highly adaptable to various soil and climatic conditions, making it ideal for degraded or unstable slopes along riverbanks.

Method

This study employed a quantitative descriptive approach to evaluate the effectiveness of Napier grass (*Pennisetum purpureum* cv. Mott) in mitigating riverbank erosion along the Pappa River in Takalar Regency, South Sulawesi, Indonesia. Conducted over a three-month period (December 2024–January 2025) during the rainy season, the research involved establishing Napier grass on critical riverbank sites and comparing its performance against control plots with other vegetation and bare soil. Data on runoff and soil erosion were collected using runoff plots installed across varying slope gradients and observed following natural rainfall events. Additional visual assessments and photographic documentation supported the analysis. The collected data were processed using descriptive statistical methods to compare runoff volumes and erosion rates between Napier grass-covered and untreated plots.

Result and Discussion

The study's results, which show the influence of vegetation cover on riverbanks on the rate of erosion, are presented in Figure 1.

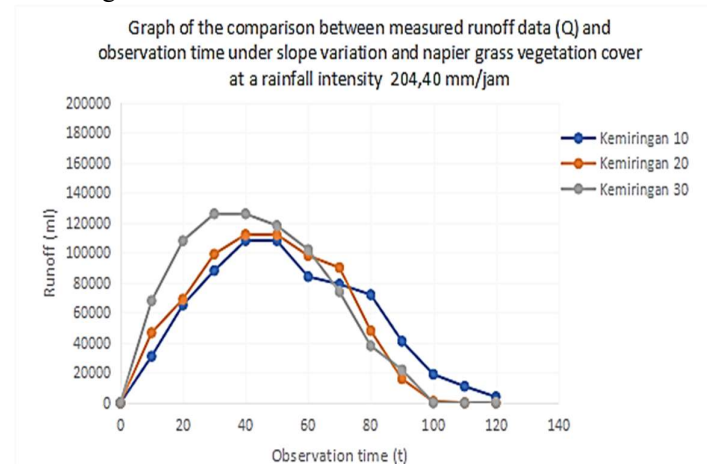


Figure 1. Erosion Rate in the rainfall condition with vegetation cover

The results indicated that on a 10° slope, the runoff measured at the tenth minute reached 108,000 mL, with a maximum of 125,800 mL maintained at the 40th and 50th minutes. The corresponding runoff rate was 12,222 mm³/s, with a cumulative rainfall intensity of 6.69 mm/s. Slope steepness significantly affected both the magnitude and timing of surface runoff, where steeper slopes produced higher runoff volumes and reached peak flow more rapidly than gentler slopes. The presence of Napier grass effectively reduced runoff by increasing infiltration and surface resistance, although its effectiveness decreased with increasing slope gradient.

The graph showed the comparison of measured runoff data (Q) over observation time (t) under varying land slope conditions and ground cover on a flat 50 × 50 cm plot planted with Napier grass, subjected to a rainfall intensity of 200.65 mm/hour. The x-axis represents observation time (t) in minutes, while the y-axis indicates measured runoff (Q) in milliliters (ml). Three colored lines show the results for different slope gradients—blue for 10°, orange for 20°, and gray for 30°.

At the beginning of the observation, all slope gradients exhibited a gradual increase in runoff, reflecting the initial accumulation of surface water. As rainfall continued, runoff rose

sharply, reaching its peak between approximately 30 and 50 minutes. The highest peak occurred on the 30° slope, followed by the 20° and 10° slopes, indicating that steeper slopes generate greater runoff due to faster surface flow and reduced infiltration capacity. After the peak, runoff progressively declined as rainfall ceased and surface water diminished, approaching near zero after about 100–120 minutes.

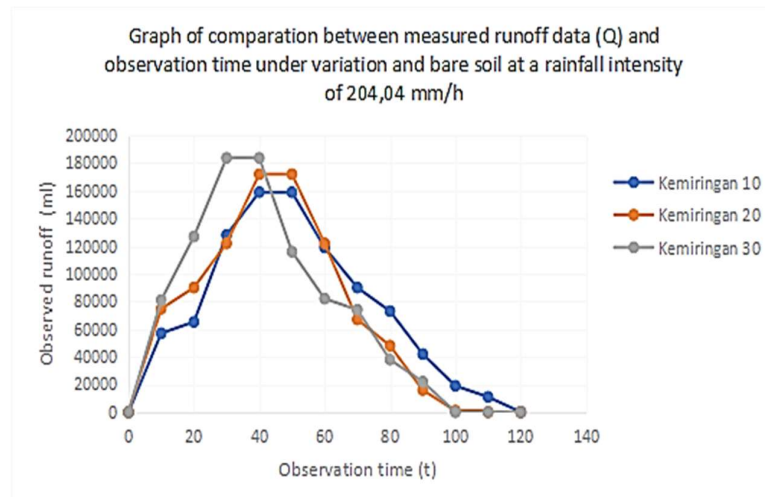


Figure 2. Erosion Rate in the Rainfall Condition Without Vegetation Cover

The graph showed the comparison between measured runoff data (Q) and observation time (t) for different slope variations on bare soil under a rainfall intensity of 204.04 mm/h. The x-axis represents observation time (t) in minutes, while the y-axis indicates the observed runoff (Q) in milliliters (ml). Three lines represent the results for different slope gradients—blue for a 10° slope, orange for a 20° slope, and gray for a 30° slope.

At the beginning of the observation, all slope gradients exhibited a gradual increase in runoff, reflecting the initial accumulation of surface water. Over time, runoff rose sharply, reaching its peak between approximately 30 and 50 minutes. The highest runoff was observed on the 30° slope, followed by the 20° and 10° slopes, demonstrating that steeper gradients generate greater and faster runoff due to reduced infiltration and accelerated overland flow. After the peak, runoff steadily declined, approaching near zero after about 100–120 minutes, indicating the cessation of surface flow. According to Zhang et al. (2022), surface runoff occurs when rainfall intensity exceeds the soil's infiltration capacity; on steeper slopes, shorter contact time between rainfall and soil further limits infiltration and amplifies runoff generation.

Overall, the results indicate a clear relationship between slope steepness and surface runoff on bare soil. Steeper slopes produce greater runoff volumes and faster peak responses, whereas gentler slopes generate lower runoff with delayed peaks. The absence of vegetation further intensifies runoff due to reduced surface resistance and limited soil infiltration. The use of grasses for riverbank conservation provides multiple ecological benefits and is often more effective than structural methods. In addition to preventing erosion, grass cover supports biodiversity by offering habitat for microorganisms and small fauna such as insects and aquatic species (Tisserant et al., 2024). However, this approach requires regular maintenance, particularly during dry seasons, as inadequate soil moisture can cause root and stem desiccation, weakening soil cohesion and increasing the risk of surface erosion.

Maintaining vegetation along riverbanks enhances their ecological function and stability. Without adequate conservation measures, riverbank degradation can disrupt the natural water cycle, reduce soil infiltration capacity, and increase the risk of erosion and landslides.

Conclusion

Field trials conducted on the riverbanks of the Pappa River, Takalar Regency, South Sulawesi, demonstrated that Napier Grass (*Pennisetum purpureum* cv. Mott) can grow well on riverbank areas. Furthermore, the grass proved to be effective in reducing surface runoff, indicating its strong potential as a vegetative alternative for riverbank protection and erosion control.

Acknowledgment

The authors would like to express their sincere gratitude to all individuals and institutions who provided valuable support and guidance during this research. Special thanks are extended to my supervisor at Universitas Negeri Makassar for their technical assistance and to the reviewers for their constructive comments, which significantly improved the quality of this manuscript. We would also like to thank the local community leaders and participants who generously shared their time and knowledge during the fieldwork.

References

- Ashraful, M. A. I., & Rahman, M. M. (2024). Effects of roadside cultivation of Napier grass (*Pennisetum purpureum* Schumach.) on wild natural vegetation of Kaliganj, Gazipur, Bangladesh. *Bangladesh Journal of Botany*, 53(4), 913–922. <https://doi.org/10.3329/bjb.v53i4.78637>
- Erita, –, Sandri Sastrawan, Salmandi Futra, & Hairunnas. (2020). The effect of soil slope and organic materials on changes of land physical properties and Napier grass (*Pennisetum purpureum*) production. *Journal of Agriculture and Ecology Research International*, 21(7), 13–21. <https://doi.org/10.9734/JAERI/2020/v21i730153>
- Galvão, T. C. D. B., Pimentel, A. L., & Ribeiro, C. S. (2018). Study of erosion control techniques applied to water reservoir margins under tropical conditions. *Athens Journal of Sciences*, 5(4), 301–316. <https://doi.org/10.30958/ajs.5-4-4>
- Islam, Aznarul, and Sanat Kumar Guchhait. 2024. “Riverbank Erosion: Basic Concepts and Approaches.” Pp. 3–22 in *Riverbank erosion in the bengal delta: An integrated perspective*. Springer.
- Islam, M. R., Akter, S., Rahman, M. M., Sarker, A., & Huque, K. S. (2023). Napier grass (*Pennisetum purpureum*): A review of agronomy, uses, and potential. *Animals*, 13(15), 2479. <https://doi.org/10.3390/ani13152479>
- Kang, Dong-Jin, and Hirofumi Tazoe. 2024. “Impacts of Soil Type and Drought Stress on Growth and Cesium Accumulation in Napier Grass.” *Environmental Geochemistry and Health* 46(7):235.
- Kelley, Lisa C., and Agung Prabowo. 2019. “Flooding and Land Use Change in Southeast Sulawesi, Indonesia.” *Land* 8(9):139.
- Li, Qiang, Lu Wang, Xudong Ma, and Ruihua Nie. 2023. “Experimental Study of the Effects of Riverbank Vegetation Conditions on Riverbank Erosion Processes.” *Environmental Fluid Mechanics* 23(3):621–32.
- Nsiah, P. K., Boateng, K. A., & Mensah, K. J. (2019). The potentials of biological geotextiles constructed from *Pennisetum purpureum* for erosion and sediment control during reclamation. *International Journal of Environmental Engineering and Natural Resources*, 6(3), 85–91. <https://doi.org/10.18178/ijoeear.6.3.85>
- Okeke, C. A., Ogbu, K. N., & Nwankwo, C. U. (2022). An integrated assessment of land use impact, riparian vegetation and lithologic variation on streambank stability in a peri-urban watershed. *Scientific Reports*, 12(1), 22271. <https://doi.org/10.1038/s41598-022-26783-0>
- Satriagasa, M. C., & Suryatmojo, H. (2020). Effectiveness of elephant grass cover (*Pennisetum purpureum*) in mitigation of soil erosion by rainwater. *agriTECH*, 40(2), 141–149. <https://doi.org/10.22146/agritech.50290>
- Supriyadi. (n.d.). Kajian cara tanam jagung bayi (*Zea mays* L.) dan rumput gajah (*Pennisetum purpureum*) terhadap besarnya erosi pada lahan miring. *Caraka Tani: Journal of Sustainable*

Agriculture. <https://doi.org/10.20961/carakatani.v20i1.20484>

Tamta, S., & Kumar, A. (2020). Effect of Napier grass shoot characteristics on runoff and sediment outflow under concentrated overland flow conditions. *International Journal of Chemical Studies*, 8(3), 1746–1752. <https://doi.org/10.22271/chemi.2020.v8.i3w.9544>

Tamta, S., & Kushwaha, D. P. (2023). Potential of roots and shoots of Napier grass for arresting soil erosion and runoff of Mollisols soils of Himalayas. *International Soil and Water Conservation Research*, 12(1), 1–13. <https://doi.org/10.1016/j.iswcr.2023.04.002>

Thampi, A. C., Prameela, P., Antony, S., & Sekhar, L. (2023). Flood tolerance of hybrid Napier (Pennisetum purpureum × Pennisetum glaucum) cultivars. *International Journal of Plant & Soil Science*, 35(21), 394–402. <https://doi.org/10.9734/ijpss/2023/v35i213989>

Tisserant, Maxime, Eduardo González-Sargas, André Evette, Béranger Bourgeois, and Monique Poulin. 2024. “A Functional Characterization of Bioengineered Plant Communities along Riverbanks.” *Ecological Engineering* 204:107279.

Utamy, R. F., Purwanto, E., & Sugiyanta, S. (2021). Mixed cropping of dwarf Napiergrass (Pennisetum purpureum cv. Mott) with Indigofera using an alley cropping system. *Open Agriculture*, 6(1), 666–675. <https://doi.org/10.1515/opag-2021-0059>

Wahyu, B., Mustaring, & Basri, M. (2022). Regrowth of dwarf elephant grass (Pennisetum purpureum cv. Mott) treated with nitrogen fertilizer in its initial development. *Jurnal Ilmiah AgriSains*, 23(3), 139–147. <https://doi.org/10.22487/jiagrisains.v23i3.2022.139-147>

Satriagasa, M. C., & Suryatmojo, H. (2020). Efektivitas tutupan rumput gajah (Pennisetum purpureum) dalam mitigasi erosi tanah oleh air hujan. *agriTECH*, 40(2), 141-149. <https://doi.org/10.22146/agritech.50290>

Zhang, Jun, Hongsong Chen, Zhiyong Fu, Zidong Luo, Fa Wang, and Kelin Wang. 2022. “Effect of Soil Thickness on Rainfall Infiltration and Runoff Generation from Karst Hillslopes during Rainstorms.” *European Journal of Soil Science* 73(4): e13288.

Scope : Environment

Article ID : 113

INTEGRATED ENVIRONMENTAL MANAGEMENT FRAMEWORK FOR HOUSEHOLD WASTE IN RESILIENT, INCLUSIVE, AND LOW-CARBON SMART CITIES

Akhmad Qosasih*, Ahman Sya, and Nadiroh

Environmental Management Department, Jakarta State University, Jakarta, Indonesia

E-mail: *akhmad.qosasih@mhs.unj.ac.id

Abstract

Household waste management is a significant challenge in sustainable urban development, particularly in rapidly growing regions. This study proposes an Integrated Environmental Management (IEM) framework to support the development of smart, resilient, inclusive, and low-carbon cities, with a focus on household waste streams. The framework integrates three key factors: (1) behavioral change and community participation, (2) technological innovation through composting and biogas systems, and (3) institutional and policy alignment with the principles of a circular economy. Based on a systematic review of international literature from 2020 to 2025 and a conceptual systems approach using a Causal Relationship Diagram (CRD), the findings reveal that integrating these three dimensions reduces methane emissions from landfills, enhances local food and economic resilience, and strengthens social cohesion. The proposed IEM framework provides a conceptual model that can be replicated to accelerate the transition toward smart, resilient, inclusive, and low-carbon cities driven by community participation.

Keywords: household waste management, circular economy, low-carbon, smart city, community participation

Introduction

Rapid urbanization has increased Indonesia's waste generation to approximately 68 million tons per year, with 40–50% originating from households (Ministry of Environment and Forestry, 2023). About 60% of this waste is organic, yet most still ends up in landfills, producing around 500 kilotons of methane annually (IPCC, 2023). Without systemic change, national landfill capacity will be exhausted within the next 5–10 years (World Bank, 2022). This issue extends beyond sanitation it is a systemic challenge related to food security, energy, and climate resilience. Therefore, an Integrated Environmental Management (IEM) approach is needed, combining social, technological, and institutional dimensions.

The core research question is: How can behavioral, technological, and institutional factors be integrated within household waste management to support the development of smart, resilient, inclusive, and low-carbon cities? The study aims to develop a conceptual model of community-based waste management that strengthens environmental and social resilience while aligning with SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action).

The theoretical foundation draws from three interrelated frameworks. The Theory of Planned Behavior (TPB) (Ajzen, 1991) explains that individual behavior is determined by intention, influenced by attitude, subjective norms, and perceived behavioral control. The Circular Economy (CE) concept (Geissdoerfer et al., 2020) emphasizes resource value retention through

reduce, reuse, recycle, and recover principles. Meanwhile, Urban Resilience (UR) theory (Meerow et al., 2016) describes cities' capacity to adapt and transform amid environmental, social, and economic stresses without losing core functions. Together, these theories form the conceptual foundation for developing an integrated IEM framework.

Method

This study employed a Systematic Literature Review (SLR) combined with a conceptual systems approach. Literature searches were conducted through Scopus, ScienceDirect, SpringerLink, and MDPI Open Access using the keywords: "household waste management," "circular economy," "urban resilience," "low-carbon city," and "community participation." Inclusion criteria covered publications from 2020 to 2025, open-access journals, and studies addressing at least one of the three dimensions: behavioral, technological, or institutional. A total of 25 primary studies were analyzed following PRISMA guidelines (Page et al., 2021). Thematic synthesis was used to identify relational patterns and construct the conceptual IEM model. Data were analyzed descriptively and systematically, and findings were visualized using a Causal Relationship Diagram (CRD) to illustrate interconnections among behavioral, technological, and institutional factors in achieving resilient and low-carbon urban systems

Results and Discussion

From the 25 studies reviewed, three main themes emerged: (1) Community Behavior and Participation. Studies (Ajzen, 1991; Strydom, 2018; Nguyen et al., 2021) confirm that individual waste behavior is shaped by attitudes, norms, and perceived control. Incentive-based initiatives such as waste banks and eco-villages significantly enhance participation (Suharso et al., 2025). (2) Technological Innovation and Circular Systems. Research (Hu et al., 2023; Singh et al., 2024) shows composting and biodigester systems reduce waste volumes while creating economic value through renewable energy and organic fertilizer. (3) Institutional and Governance Factors. Decentralized policies and cross-sector collaboration enhance effectiveness (Rahman et al., 2022; Lim et al., 2022). Governance quality is thus as critical as technology.

The results of the literature synthesis indicate that the household waste management system is interconnected and influenced by social, technological, and institutional factors. This relationship is depicted in a Causal Relationship Diagram (CRD) as in Figure 1, with a (+) sign indicating a positive correlation and a (-) sign indicating an inverse correlation. The system comprises three interconnected subsystems —behavioral, technological, and institutional, with feedback loops indicating reinforcement (R) and balancing (B) dynamics. The reinforcing loop (R) occurs when increased community participation enhances the utilization of technology, thereby improving efficiency and generating positive economic impacts that, in turn, strengthen environmental awareness and participation. Conversely, the balancing loop (B) arises when policy support or incentives decline, leading to reduced community participation and a subsequent weakening of the overall system. The system is (1) Behavioral Subsystem. Community engagement is a key element in the IEM framework. Increasing environmental awareness (+) will encourage community participation in waste sorting at source. High participation (+) will reduce the amount of waste sent to landfills (-). Reducing the volume of waste sent to landfills (+) will reduce methane emissions (-). Conversely, low levels of community participation weaken the circular system and increase the burden on landfills. This aligns with the findings of Nguyen et al. (2021) and Suharso et al. (2025), which confirmed that the community's pro-environmental behavior directly influences a city's carbon emissions. (2) Technological Subsystem. Technological innovation plays a key role in connecting behavior and environmental outcomes. Waste sorting at source is positive (+) and will increase the effectiveness of organic processing technologies such as composting and biodigesters. This technology produces fertilizer and

renewable energy, which are positive (+), thereby strengthening food security and the local economy. Studies by Hu et al. (2023) and Singh et al. (2024) show that implementing a waste-to-resource system can reduce carbon footprints by 30–40% at the urban community level. (3) Institutional Subsystem. Institutions become the regulators of systems that ensure sustainability and social justice. Policies that support participatory incentives (+) will improve sorting and processing behavior at the household level (+). Cross-sectoral coordination (+) will strengthen the implementation of technological innovation (+). However, centralized policies (–) or the lack of incentive mechanisms (–) can weaken participatory and inclusive systems. Literature by Rahman et al. (2022) and Mohanty et al. (2022) shows that the synergy between local policies and community participation strongly influences the success of waste management in Asian cities.

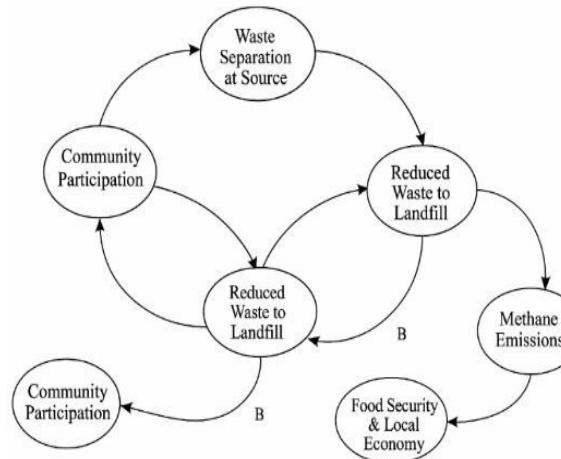


Figure 1. Causal Relationship Diagram (CRD) in the IEM Framework

Linkage of IEM framework with smart, resilient, inclusive, and low-carbon cities: (1) Smart cities leverage data and technology to enhance efficiency and citizen engagement. IEM promotes digitalization in waste systems through Material Flow Analysis (MFA) and online waste bank applications. Digital participation reinforces pro-environmental behavior and enables data-driven policy monitoring (Zhang et al., 2021; Hapsari et al., 2023). (2) Resilience refers to a city's capacity to adapt to environmental, social, and economic stress. Through IEM, the use of organic waste for energy and compost enhances local food-energy resilience and reduces dependency on external resources (Pradhan et al., 2024; Singh et al., 2024). (3) IEM fosters collaboration among governments, communities, and private sector through waste bank and eco-village programs. Incentive schemes and equitable benefit-sharing empower vulnerable groups to participate actively in the circular economy (Su et al., 2025; Lim et al., 2022). (4) Reducing organic waste sent to landfills directly lowers methane (CH₄) emissions, which are 28 times more potent than CO₂ (Abubakar, 2022). Biodigester technology substitutes fossil fuels and chemical fertilizers, promoting climate mitigation (Chekol, 2024). Overall, IEM plays a strategic role in realizing cities that are technologically smart, socially resilient, economically inclusive, and ecologically low-carbon

Conclusion

IEM framework effectively integrates three essential dimensions (community behavior, technological innovation, and institutional governance). The conceptual CRD demonstrates that: (1) Increased community participation significantly reduces landfill waste and methane emissions. (2) Composting and biodigester technologies generate new economic value while strengthening food security. (3) Collaborative governance sustains circular systems and social inclusivity. Overall, IEM serves not only as a technical solution but also as a cross-sectoral conceptual model linking climate mitigation, social empowerment, and urban economic

Recommendations

1. For local governments: implement cross-sector collaboration and provide economic incentives for households and communities adopting circular systems.
2. For researchers: expand IEM through quantitative system dynamics modeling to assess variable sensitivity and long-term impacts.
3. For communities and private sectors: integrate small-scale composting and biodigester technologies with digital platforms and continuous training.
4. For national policymakers: adopt IEM as a replicable model supporting Nationally Determined Contributions (NDCs) and SDGs 11 and 13.

Acknowledgment

The author expresses sincere gratitude to academic colleagues and the State University of Jakarta for institutional and technical support. Special appreciation is extended to experts involved in peer debriefing for enhancing methodological rigor and conceptual clarity.

References

- Abubakar, I. (2022). *Methane emission reduction through organic waste management in urban areas*. *Journal of Environmental Management*, 305(4), 114–123. <https://doi.org/10.1016/j.jenvman.2022.114123>
- Ajzen, I. (1991). *The theory of planned behavior*. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Budiyarto, A., Kurniawan, R., & Sari, D. (2024). *Circular economy transition in Indonesian urban waste management systems*. *Sustainability*, 16(2), 1124. <https://doi.org/10.3390/su16021124>
- Chen, H., Li, X., & Xu, J. (2021). *Integrating low-carbon strategies in urban environmental systems*. *Cleaner Cities*, 9(1), 45–58
- Chekol, B. (2024). *Household composting as a low-carbon solution in developing cities*. *Urban Sustainability Journal*, 5(3), 221–230
- Darmawan, A., Fitri, M., & Prabowo, H. (2023). *Circular waste system integration for sustainable urban management*. *Environmental Systems Research*, 12(1), 88–97
- Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2020). *The circular economy – A new sustainability paradigm?* *Journal of Cleaner Production*, 263, 121–132. <https://doi.org/10.1016/j.jclepro.2020.121132>
- Hapsari, D., Wibowo, Y., & Prasetyo, F. (2023). *Citizen participation in smart city environmental programs: A case from Indonesia*. *Smart Cities and Society*, 12(1), 67–79
- Hu, Z., Yang, Y., & Chen, L. (2023). *Technological innovation and circular economy in urban waste management*. *Journal of Environmental Science and Technology*, 57(2), 100–115
- Junaidi, F., & Sari, N. (2024). *Green innovation policies and waste reduction initiatives*. *Policy and Environmental Studies*, 13(1), 54–68
- Kurniawati, I., Raharjo, A., & Putri, S. (2023). *Eco-village models for community-based organic waste management*. *International Journal of Sustainable Development*, 29(4), 235–247.
- Lim, C., Tan, S., & Rahman, A. (2022). *Community-led recycling initiatives in Southeast Asian cities*. *Waste Management & Research*, 40(9), 1240–1253
- Liu, J., Wang, S., & Chen, Y. (2020). *Behavioral change and sustainable waste management*. *Resources, Conservation and Recycling*, 161, 104973
- Meerow, S., Newell, J. P., & Stults, M. (2016). *Defining urban resilience: A review*. *Landscape* 1st ICE3SHT 2025

- and *Urban Planning*, 147, 38–49. <https://doi.org/10.1016/j.landurbplan.2015.11.011>
- Mohanty, R., Kumar, D., & Sen, S. (2022). *Local governance and circular transition in urban waste policy*. *Sustainability Science*, 17(3), 1405–1418
- Nguyen, T. N., Lobo, A., & Greenland, S. (2021). *Pro-environmental behavior and waste separation intention: Testing TPB in Vietnam*. *Resources, Conservation and Recycling*, 164, 105210.
- Page, M. J., McKenzie, J. E., & Bossuyt, P. M. (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews*. *BMJ*, 372, n71
- Pradhan, P., Costa, L., & Singh, S. (2024). *Urban resilience through integrated food and waste systems*. *Environmental Research Letters*, 19(1), 014020.
- Rahman, M., Idris, A., & Taufik, M. (2022). *Governance and decentralization in waste policy implementation*. *Journal of Urban Affairs*, 44(6), 1083–1095
- Singh, S., Patel, A., & Sharma, P. (2024). *Waste-to-energy innovation for sustainable cities*. *Renewable Energy and Sustainability*, 18(2), 255–268
- Strydom, W. (2018). *Applying the theory of planned behavior to recycling behavior in South Africa*. *Waste Management*, 75, 19–27
- Su, X., Li, Q., & Han, J. (2025). *Inclusive urban development and citizen engagement in environmental governance*. *Sustainable Cities and Society*, 104, 105015
- Suharso, A., Hartati, E., & Puspita, D. (2025). *Community-based incentives for household waste reduction in Indonesia*. *Asian Journal of Environmental Management*, 7(1), 32–46
- Wijayanti, R., Gunawan, F., & Lestari, N. (2023). *Urban composting and food security: Linking waste and agriculture*. *Journal of Urban Agriculture and Environment*, 8(3), 155–168.
- Zhang, H., Liu, R., & Zhao, Y. (2021). *Smart governance and data-driven waste management systems*. *Cities*, 115, 103241

Scope : Environment

Article ID : 114

URBAN FARMING AS A PATHWAY TO STRENGTHEN COMMUNITY ADAPTIVE CAPACITY TO CLIMATE CHANGE: OPPORTUNITIES AND CHALLENGES FROM MAKASSAR CITY

Moh. Ahsan S Mandra*, Abdul Gafur, and Eka Apriyanti

*Graduate Program in Population and Environmental Education, Universitas Negeri Makassar,
Makassar, Indonesia*

E-mail: *mohammad.ahsan.sm@unm.ac.id

Abstract

This study investigates urban farming as a strategy to strengthen community adaptive capacity to climate change in Makassar City, Indonesia. Employing a qualitative descriptive approach through interviews, observations, and policy analysis, the research highlights urban farming's role in enhancing household food security, local economic resilience, and environmental awareness. It also facilitates social networks and collaboration to address climate-related risks. However, key challenges persist, including limited land, insufficient technical and financial support, weak policy frameworks, and low public literacy on sustainable agriculture. The study concludes that the success of urban farming depends on strong synergy between communities, government, academia, and the private sector through regulatory support, funding, and innovation. Urban farming should therefore be recognized not only as a food production practice but also as a sustainable climate adaptation strategy integrated into urban development planning.

Keywords: urban farming; adaptive capacity; climate change; Makassar; opportunities and challenges

Introduction

Climate change has become the most pressing global challenge, especially for coastal urban areas (Yi, 2024; Day et al., 2021; Caprario et al., 2022). Cities such as Makassar face high risks due to rising temperatures, extreme rainfall, and increased frequency of hydrometeorological disasters that have a direct impact on environmental sustainability and community welfare (Ismayanti & Aljurida, 2023; Worku & Terefe, 2023; Toth, 2024; Mejía & Gomez, 2023). In the local context, climate change has affected the availability of water resources and increased the potential for urban flooding that disrupts people's economic activities (Awaluddin et al., 2024; Teoh et al., 2024; Abdul Rashid et al., 2023).

In Indonesia, various studies confirm that urban farming not only increases food independence, but also strengthens the household economy, especially vulnerable groups (Wijaya, 2022; Barokah et al., 2023; Maulana et al., 2024). In the context of Makassar, urban farming contributes to family food security through the use of city hallways as a space for chili and vegetable production (Isdialah, 2023). This shows that urban farming has strategic potential in answering urban food problems while reducing vulnerability to the climate crisis.

Urban farming is not only a food fulfilment strategy, but also a form of community adaptation to climate change. This practice is able to reduce micro temperatures in densely populated environments, improve air quality, and increase socio-ecological resilience (Henzelmann, 2023; Luo et al., 2023; Mensah, 2023). In Makassar, the practice of alley,

hydroponics, and urban farming based on sustainable architectural design has begun to be implemented by the community in response to food needs as well as environmental adaptation strategies (Najib et al., 2025; Awaluddin et al., 2024). Studies also show that urban farming can increase community empowerment through the creative economy and green literacy that contribute to the family economy (Surya et al., 2020; Baharuddin et al., 2024).

Meanwhile, qualitative studies of local communities confirm that urban farming is often constrained by social capital, policy networks, and access to technology (Baharuddin et al., 2024). Thus, this study aims to explore how urban farming is applied in Makassar City and the extent to which the practice increases the community's adaptation capacity to climate change. The focus is directed at identifying opportunities and challenges so that urban farming can develop as a sustainable adaptation strategy that is relevant to local needs while being aligned with the global agenda of climate change mitigation.

Method

This research uses a qualitative approach with a case study design to understand the dynamics of urban farming implementation and community adaptation capacity to climate change in Makassar City. The research locations were determined at several urban farming points in Makassar City, which were selected based on the criteria of active community involvement, institutional support, and variations in the form of urban farming practices. The selected areas include community lands, school-based urban gardens, and self-help initiatives in densely populated areas. Primary data was collected through in-depth interviews, focus group discussions (FGDs), and participatory observations. The research informants included urban farmers, community managers, local government officials, as well as support groups such as NGOs and academics. Interviews are used to explore individual experiences, while FGDs aim to capture collective dynamics and shared perspectives on the challenges and opportunities of urban farming. Participatory observation was carried out to record daily activities, interaction patterns, and the use of simple technology in urban farming practices. Data analysis was carried out using thematic techniques based on grounded theory (Roldugin, 2023; Creswell & Poth, 2018).

Result and Discussion

The research found that urban farming in Makassar develops through various forms of practices, ranging from community gardens to the use of household yard land. Some communities have successfully integrated vertical farming and simple hydroponics, especially in dense urban areas with little open land. This innovation shows that communities are able to adapt appropriate technology to deal with space limitations, while maintaining local food productivity. These findings are in line with previous studies which stated that innovative farming methods allow communities to adapt to space constraints while maintaining local food productivity (Jain et al., 2025; Zhou, 2024). This is proof that the physical limitations of the city are not completely an obstacle in building community-based food security.

In terms of climate adaptation, urban farming practices have been proven to contribute to environmental risk management, especially in reducing the impact of urban temperatures. Field observations show that areas with high urban farming intensity have a better level of microclimate comfort than areas without vegetation. These findings are consistent with research highlighting the role of urban green spaces in lowering local temperatures and increasing people's adaptive capacity to heat waves (Rahman & Hasan, 2024). Thus, urban farming not only contributes to food production but also provides important ecosystem services.

However, the results of the study also show significant limitations, particularly in terms of institutional support. Many urban farming communities still operate independently without ongoing assistance from the city government. This condition has an impact on limited access to

superior seeds, organic fertilizers, and efficient water management technology. Similar barriers are also found in other cities in Indonesia, where urban farming is doing well at the initiation stage but is difficult to survive without structural support (Hanifa et al., 2023). Therefore, the sustainability of the initiative is greatly influenced by partnerships between communities, governments, and the private sector.

From an economic perspective, urban farming in Makassar provides real benefits even on a small scale. The residents involved reported savings of up to 20–30 percent in daily vegetable shopping, as well as additional income from the sale of fresh produce at the local market. These benefits are in line with international studies showing that urban agriculture plays a role as an effective microeconomic strategy, especially among low-income communities (Siegener et al., 2018). These findings strengthen the argument that urban farming not only has an ecological impact but also contributes to household economic resilience.

The research also found that urban farming functions as a means of environmental education, especially for the younger generation. Some schools in Makassar have integrated learning gardens as part of the practical curriculum, so that students can understand the linkages between food, the environment, and climate change. This program strengthens ecological awareness while instilling sustainability values from an early age. Thus, urban farming contributes to the transformation of people's behaviour towards a more pro-environmental lifestyle. This finding is in line with the study of Prasetyo (2018) which states that urban farming school projects in Bandung have been particularly effective in teaching children about ecology, fostering an ecological mentality, and encouraging environmentally significant behaviour.

Overall, the results of the study show that urban farming in Makassar offers great opportunities in strengthening the capacity of community adaptation to climate change. The practice provides ecological, social, and economic benefits at the same time, although it still faces significant structural challenges. With policy support, technology access, and institutional strengthening, urban farming has the potential to be a key strategy in building cities that are more resilient to climate change. The following table is an overview of thematic analysis and transcript interpretation of some key informants.

Table 1. Thematic analysis of urban farming in Makassar

Theme	Sub-theme	Interpretation
Urban Farming Innovation	Limited land adaptation	Residents developed simple vertical farming techniques to overcome space constraints in urban areas.
	Simple technology	Digital knowledge supports the adoption of household-scale urban agriculture technology.
Climate Adaptation Capacity	Adjustment of planting patterns	Communities integrate local climate data with traditional knowledge in selecting crops.
	Response to rainfall	Scientific data from BMKG is used as a reference for climate adaptation in urban farming practices.
Socio-Economic Benefits	Shopping savings	Urban farming has a direct economic impact through saving food costs.
	Community solidarity	Urban farming strengthens social networks and togetherness of urban residents.
Challenges and Obstacles	Limited policy support	The sustainability of urban farming is constrained by the lack of policy support and technical assistance.
	Access resources	Limited access to agricultural inputs is the main obstacle for urban farmers.
Environmental Education and Awareness	Schoolchildren's learning	Urban farming functions as a medium for environmental education and builds awareness from an early age.
	Climate awareness	Participation in urban farming increases citizens' climate awareness and pro-environmental behavior.

The findings of this study show that urban farming in Makassar has great potential in increasing the capacity of community adaptation to climate change. This practice not only provides economic and social benefits, but also contributes to the improvement of the

microclimate as well as the strengthening of environmental awareness. However, the results also confirm that there are serious barriers in the form of limited institutional support, access to resources, and program sustainability.

Conclusion

This study shows that the implementation of *urban farming* in Makassar City has strategic potential as one of the approaches to community adaptation to climate change. This practice not only serves as an effort to utilize limited space in urban areas, but also strengthens adaptation capacity through increased knowledge, community participation, and diversification of livelihoods. Empirical data obtained from in-depth interviews and thematic analysis confirm that urban communities are beginning to realize the ecological and social value of *urban farming*, thus making it an alternative solution in the face of increasing climate risks.

Acknowledgment

Thank you to the head of the research and community service institute (LP2M) of Universitas Negeri Makassar and the staff who have helped in completing the process of this research.

References

- Abdul Rashid, N. F., Anuar, H. H., & Raja Safwan, R. S. (2023). Urban farming: solar nutrient film technique system. *International Journal of Innovation and Industrial Revolution*, 5(13), 149–157. <https://doi.org/10.35631/ijirev.513013>
- Barokah, U., Rahayu, W., & Antriyandarti, E. (2023). The role of urban farming to household food security in the surakarta city, indonesia. *Agrisocionomics*, 7(3), 526–538. <https://doi.org/10.14710/agrisocionomics.v7i3.15942>
- Caprario, J., Tasca, F. A., Santana, P., Azevedo, L. T. S., & Finotti, A. R. (2022). Framework for incorporating climate projections in the integrated planning and management of urban infrastructure. *Urban Climate*, 41, 101060. <https://doi.org/10.1016/j.uclim.2021.101060>
- Creswell, J. W., & Poth, C. (2018). *Qualitative Inquiry and Research Design (International Student Edition): Choosing Among Five Approaches*.
- Day, J. W., Gunn, J. D., & Burger, J. R. (2021). Diminishing Opportunities for Sustainability of Coastal Cities in the Anthropocene: A Review. *Frontiers in Environmental Science*, 9. <https://doi.org/10.3389/FENV.2021.663275>
- Henzelmann, M. (2023). The Effectiveness of Urban Farming in Urban Heat Island Mitigation in Urban Areas. *Atrium*, 8(3), 189–198. <https://doi.org/10.21460/atrium.v8i3.200>
- Ismayanti, I., & Aljurida, A. M. A. (2023). Urgency in Urban Flood Disaster Mitigation: Response and Policy Initiation by Makassar City Government. *Journal of Governance and Local Politics (JGLP)*. <https://doi.org/10.47650/jglp.v5i2.954>
- Jain, A., Arora, V., Linzara, H., & Saraswat, O. (2025). *Vertical Farming and Hydroponics Leveraging Smart Technologies for Urban Agriculture*. 187–210. <https://doi.org/10.4018/979-8-3373-5283-1.ch007>
- Najib, M. A., Marwati, M., & Nursyam, N. (2025). The application of the passive and active concept of sustainable architecture in the design of urban farming centers in Makassar City. *TIMPALAJA: Architecture Student Journals*, 7(1), 25–36. <https://doi.org/10.24252/timpalaja.v7i1a3>
- Rahman, Md. M., & Hasan, J. (2024). Evaluating the Impact of Green Spaces on Urban Heat Reduction in Rajshahi, Bangladesh Using the InVEST Model. *Land*, 13(8), 1284. <https://doi.org/10.3390/land13081284>
- Roldugin, I. (2023). Thematic Analysis. *Springer Texts in Education*, 463–468. https://doi.org/10.1007/978-3-031-04394-9_72

- Siegner, A., Sowerwine, J., & Acey, C. (2018). Does Urban Agriculture Improve Food Security? Examining the Nexus of Food Access and Distribution of Urban Produced Foods in the United States: A Systematic Review. *Sustainability*, 10(9), 2988. <https://doi.org/10.3390/SU10092988>
- Toth, A. (2024). *Enhancing Food Resilience in the Age of Geoeconomics by Applying Biomimetic Principles in Urban Agriculture*. <https://doi.org/10.20944/preprints202409.2407.v1>
- Prasetyo, W. H. (2018). *Fostering Environmental Virtue for Children through School Urban Farming in Bandung, Indonesia*. 250–255. <https://doi.org/10.2991/ACEC-18.2018.59>
- Worku, A., & Terefe, M. K. (2023). Effect of climate change on food security. *Ratarstvo i Povrtarstvo*, 60(1), 20–25. <https://doi.org/10.5937/ratpov60-40400>
- Wijaya, S. M. (2022). Urban Farming in Food Security Efforts at Household Level in Indonesia: Systematic Review. *International Journal of Current Science Research and Review*, 05(09). <https://doi.org/10.47191/ijcsrr/v5-i9-13>
- Yi, Q. (2024). Urban Planning Strategies for Coastal Cities in China in Response to Climate Change. *Advances in Economics, Management and Political Sciences*, 123(1), 20–25. <https://doi.org/10.54254/2754-1169/123/2024mur0116>
- Zhou, Y. (2024). Technological Innovation and Significance of Vertical Farming System in High-Density Urban Areas. *E3S Web of Conferences*, 579, 03001. <https://doi.org/10.1051/e3sconf/202457903001>

Scope : Environment

Article ID : 115

EVALUATION OF PHARMACEUTICAL WASTEWATER MANAGEMENT AND HORMONAL IMPACT ON GROUNDWATER POLLUTION IN CIRACAS, EAST JAKARTA

Hasnah Lidiawati, Eliana Sari, and Muhammad Zid

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *hasnah.lidiawati@mhs.unj.ac.id

Abstract

Pharmaceutical wastewater is classified as hazardous (B3) and may contain active hormonal compounds such as ethinyl estradiol, estradiol, and estrone. These compounds are persistent in the environment and can contaminate groundwater, posing risks to human health and ecosystems. This study aims to evaluate the wastewater management system of a pharmaceutical industry in Ciracas, East Jakarta, and to analyze hormone concentrations in both wastewater and surrounding groundwater. Samples were collected using the grab sampling method within a 0–200 m radius from the discharge point and analyzed by Solid Phase Extraction (SPE) followed by Liquid Chromatography–Mass Spectrometry/Mass Spectrometry (LC–MS/MS). Results showed that estradiol (45 ± 5 ng/L), ethinyl estradiol (25 ± 3 ng/L), and estrone (30 ± 4 ng/L) concentrations exceeded international thresholds, while hormone residues were still detected in groundwater up to 20 ng/L. These findings emphasize the need for stricter and more sustainable wastewater management practices.

Keywords: pharmaceutical wastewater; hazardous waste B3; hormones; LC-MS/MS; groundwater contamination

Introduction

The pharmaceutical industry produces wastewater containing Active Pharmaceutical Ingredients (APIs), including hormonal compounds such as 17α -ethinylestradiol (EE2), 17β -estradiol (E2), and estrone (E1). These endocrine-disrupting chemicals (EDCs) are persistent, bioaccumulative, and harmful to both ecosystems and human health, even at nanogram-per-liter concentrations. Previous international studies (2020–2025) have shown that E1, E2, and EE2 remain detectable in industrial effluents even after conventional treatment, indicating their persistence in aquatic environments. Solid Phase Extraction (SPE) combined with Liquid Chromatography–Mass Spectrometry/Mass Spectrometry (LC–MS/MS) remains the standard for detecting trace-level hormonal compounds.

In Indonesia, industrial wastewater is regulated under the Ministry of Environment and Forestry Regulation No. 5 of 2014, and groundwater quality is regulated under the Ministry of Health Regulation No. 32 of 2017. However, these do not yet specify limits for hormonal residues or EDCs. The absence of specific standards may allow hormones to infiltrate groundwater, posing environmental and health risks. Studies (2021–2024) have shown that EE2 at 1–10 ng/L and E2 at 10–40 ng/L can cause reproductive disruption in aquatic species—the European Union and WHO have recognized these risks and are developing environmental hormone residue standards.

The pharmaceutical industrial area in Ciracas, East Jakarta, is densely populated and dependent on groundwater. Without specific regulations and advanced wastewater treatment,

hormone infiltration poses a significant risk. Therefore, this study aims to: (1) identify and quantify hormonal compounds in pharmaceutical wastewater, (2) evaluate hormone concentrations in groundwater at 0–200 m from discharge points, and (3) assess the alignment of the existing management system with international best practices and national regulations. Findings are expected to provide technical and policy guidance for developing hormone-related wastewater standards in Indonesia.

Method

This study was conducted at a pharmaceutical manufacturing facility in Ciracas, East Jakarta. Sampling points included three wastewater outlets and four groundwater wells at 0 m, 50 m, 100 m, and 200 m from the discharge source. Grab sampling was performed during production hours using sterilized amber bottles, stored at 4°C, and analyzed within 24 hours. Hormonal compounds (EE2, E2, E1) were extracted using Solid Phase Extraction (SPE) and quantified using LC–MS/MS. Supporting parameters such as pH, COD, TSS, and TOC were measured and compared against national wastewater standards.

Statistical analysis was conducted using Pearson correlation and ANOVA to determine the relationship between hormone concentrations in wastewater and groundwater at varying distances. Data were processed using Microsoft Excel and SPSS to ensure precision and reproducibility.

Result and Discussion

The physicochemical characteristics of wastewater were within Indonesian regulatory limits: pH 6.7 ± 0.3 , COD 210 ± 25 mg/L, TSS 35 ± 5 mg/L, and TOC 28 ± 4 mg/L. However, hormonal concentrations exceeded international thresholds, with average levels of E2 at 45 ± 5 ng/L, EE2 at 25 ± 3 ng/L, and E1 at 30 ± 4 ng/L. Groundwater samples showed decreasing hormone concentrations from 20 ng/L near the source to <3 ng/L at 200 m, indicating attenuation through adsorption, dilution, and partial degradation. The strong correlation ($R^2 = 0.84$) between wastewater and groundwater hormone levels confirms infiltration through soil and potential risk of groundwater contamination.

These findings are consistent with Kim et al. (2019) and Prokic et al. (2020), who found that estrogenic compounds persist after secondary treatment due to their hydrophobic nature and limited biodegradability. EE2 and E2 can adsorb to organic matter and sediments, remaining bioavailable even at low concentrations. Similar outcomes were reported by Adeel et al. (2022) and Han et al. (2024), who documented reproductive disruption in aquatic organisms at ng/L exposure levels.

Comparative analysis with international studies shows that E2 levels detected in this study (45 ng/L) exceed the European Union's environmental quality threshold of 10 ng/L. This suggests that existing treatment technologies in the Ciracas facility are inadequate for hormone removal. The absence of tertiary treatment—such as ozonation, activated carbon adsorption, or membrane filtration—likely explains the elevated concentrations. Xu et al. (2021) and Klaic et al. (2022) reported that advanced oxidation and adsorption technologies can remove more than 90% of estrogenic compounds, offering practical solutions for industrial adaptation in Indonesia.

In addition, the measured attenuation with distance suggests partial natural filtration, but not complete removal, highlighting potential risks for communities relying on shallow wells. Interviews with local residents supported analytical data; respondents reported odor and discoloration of groundwater near effluent outlets. These qualitative findings emphasize visible contamination effects that coincide with measured hormone residues.

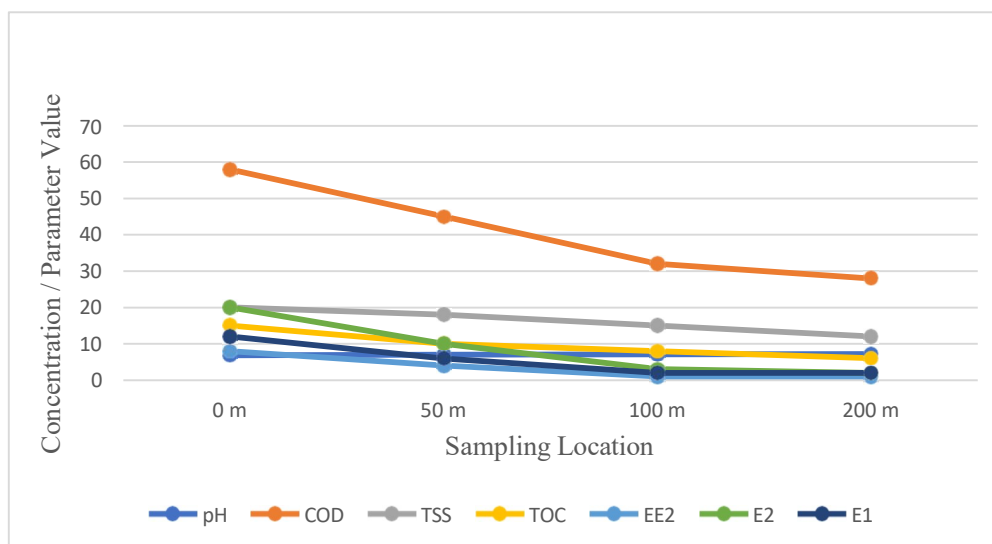


Figure 1. Variation of Water Quality Parameters with Distance from Wastewates Source

It shows how each parameter changes with increasing distance, indicating that hormone concentrations (EE2, E2, E1) drop sharply, while pH, COD, and TSS remain stable and within environmental standards.

From a regulatory perspective, Indonesia's current wastewater quality standards (MOEF, 2014) and groundwater quality regulations (MOH, 2017) do not address hormonal pollutants. Establishing hormone-specific parameters, as adopted by the EU Water Framework Directive and WHO guidelines, is crucial for comprehensive water safety management. The inclusion of endocrine-disrupting compounds in national monitoring programs would improve the environmental risk assessment of pharmaceutical industries.

To ensure sustainable management, industries should implement advanced tertiary treatment systems combined with periodic groundwater monitoring. Policies must also encourage the use of cleaner production technologies and integrate EDC monitoring into wastewater discharge permits. Collaborative efforts among government agencies, academia, and industries are necessary to strengthen environmental protection, especially in densely populated industrial regions like Ciracas.

Conclusion

Pharmaceutical wastewater in Ciracas, East Jakarta, contains elevated concentrations of EE2, E2, and E1, which persist after treatment and infiltrate the surrounding groundwater. Hormone concentrations exceeded international benchmarks, showing apparent attenuation with distance but continuous detection up to 200 m from discharge points. These results indicate that existing wastewater management systems are insufficient for the complete removal of hormonal pollutants.

The findings highlight the urgent need for implementing tertiary treatment technologies such as ozonation or activated carbon filtration and for including endocrine-disrupting chemicals in Indonesia's wastewater regulations. Future studies should focus on treatment optimization, long-term monitoring, and public awareness to minimize exposure risks. Cross-sector collaboration between environmental and health authorities will be essential to strengthen national water protection policies.

Acknowledgment

The author expresses sincere gratitude to the analytical chemistry laboratory staff for their

technical support and to the residents of Ciracas for their cooperation during field sampling. Appreciation is also extended to Universitas Negeri Jakarta for academic guidance and research facilitation.

References

- Adeel, M., Song, X., Wang, Y., Francis, D., & Yang, Y. (2022). Environmental impact of estrogens on human, animal, and plant life: A critical review. *Environment International*, 159, Article 107020. <https://doi.org/10.1016/j.envint.2021.107020>
- Bexfield, L. M., et al. (2019). Hormones and pharmaceuticals in groundwater are used as a source of drinking water across the United States. *Environmental Science & Technology*, 53, 1597–1609. <https://doi.org/10.1021/acs.est.8b05592>
- Chen, J., Liu, X., & Qiao, J. (2019). Removal of pharmaceutical hormones by advanced oxidation processes. *Journal of Environmental Chemical Engineering*, 7(4), Article 103215. <https://doi.org/10.1016/j.jece.2019.103215>
- Cuerda-Correa, E. M., Alexandre-Franco, M. F., & Fernández-González, C. (2020). Advanced oxidation processes for the removal of antibiotics from water: An overview. *Water*, 12(1), 102. <https://doi.org/10.3390/w12010102>
- European Commission. (2018). Technical report on endocrine-disrupting chemicals in water. EC Publications.
- Frimodig, J., et al. (2023). Removal of estrogens from aqueous solutions using 3D-printed activated carbon composites. *Environmental Science: Advances*. <https://doi.org/10.1039/D3VA00159H>
- Grzegorzec, M., Wartalska, K., & Kowalik, R. (2024). Occurrence and sources of hormones in water resources—Environmental and health impact. *Environmental Science and Pollution Research*, 31, 37907–37922. <https://doi.org/10.1007/s11356-024-33713-z>
- Guerrero-Gualán, D., Valdez-Castillo, E., Crisanto-Perrazo, T., & Toulkeridis, T. (2023). Methods of removal of hormones in wastewater. *Water*, 15(2), 353. <https://doi.org/10.3390/w15020353>
- Han, Y., et al. (2024). Occurrence and risk assessment of endocrine-disrupting contaminants in effluent and sludge from WWTPs. *Frontiers in Environmental Science*. <https://doi.org/10.3389/fenvs.2024.1409011>
- Klaic, M., et al. (2022). 17 α -Ethinylestradiol (EE2): Concentrations in the environment and methods for wastewater treatment—an update. *RSC Advances*, 12. <https://doi.org/10.1039/D2RA00915C>
- Liyanage, S., Lay, M., Glasgow, G., Tanner, C., Craggs, R., & Northcott, G. (2024). Nature-based solutions for the removal of steroid estrogens in wastewater. *Frontiers in Microbiology*, 15, Article 1437795. <https://doi.org/10.3389/fmicb.2024.1437795>
- Lu, Z., Li, Y., & Zhang, L. (2021). Evaluation of estrogen removal efficiency using activated carbon filtration. *Environmental Pollution*, 285, 117298. <https://doi.org/10.1016/j.envpol.2021.117298>
- Ministry of Environment and Forestry of the Republic of Indonesia. (2014). Regulation of the Minister of Environment and Forestry No. 5 of 2014 on Wastewater Quality Standards. Jakarta: Ministry of Environment and Forestry.
- Ministry of Health of the Republic of Indonesia. (2017). Regulation of the Minister of Health No. 32 of 2017 on Drinking Water Quality. Jakarta: Ministry of Health.
- Prokic, D., et al. (2020). Removal of estrone, 17 β -estradiol, and 17 α -ethinylestradiol using activated carbon cloths. *Environmental Engineering Research*, 25, Article 9758. <https://doi.org/10.1007/s12221-020-9758-2>

- Reis, R. L., et al. (2023). Electrochemical degradation of 17 α -ethinylestradiol (EE2) in water: Mechanisms and kinetics. *Environmental Research*, 234, 115954. <https://doi.org/10.1016/j.envres.2023.115954>
- Sharma, R., & Singh, P. (2020). Groundwater contamination from pharmaceutical effluents. *Environmental Monitoring and Assessment*, 192, 526.
- US Environmental Protection Agency. (2020). Technical fact sheet: Endocrine-disrupting chemicals (EDCs). US EPA.
- Wang, C., & Chen, L. (2022). Migration of pharmaceuticals through soil and groundwater systems. *Environmental Science & Technology*, 56(3), 1814–1823.
- WHO. (2018). Endocrine-disrupting chemicals in drinking water: Risk assessment and management. World Health Organization.
- Xu, H., Zhang, D., & Liu, Z. (2021). Removal of hormones from wastewater using ozone and UV processes. *Journal of Hazardous Materials*, 402, 123561. <https://doi.org/10.1016/j.jhazmat.2020.123561>

IMPACT OF INDUSTRY, TRAFFIC CONGESTION, AND GREEN OPEN SPACES ON TROPOSPHERIC OZONE CONCENTRATIONS

Robert Kurniawan^{1*}, Agung Purwanto², and Bagus Sumargo³

¹Department of Statistical Computing, Politeknik Statistika STIS, Jakarta, Indonesia.

^{1,2}Department of Population and Environmental Education, State University of Jakarta, Jakarta, Indonesia.

³Department of Statistics, State University of Jakarta, Jakarta, Indonesia

E-mail: *robertk@stis.ac.id

Abstract

This study seeks to evaluate the influence of industrial quantity, traffic congestion, and green open spaces on ozone (O₃) levels in the urban region of Jakarta, Indonesia. The linear regression analysis method was employed to ascertain the impact of each variable on the O₃ concentration. The results showed that the number of industries had a significant positive effect on the rise in O₃ concentrations, with a coefficient of 0.0009 ($p < 0.01$). Traffic congestion significantly increases O₃ concentration, with a coefficient of 0.1439 ($p < 0.05$). With a coefficient of -0.1296 ($p < 0.05$), the amount of green open space (GOS) had a significant negative effect on the concentration of O₃. This means that more green open space is linked to lower O₃ concentration. These findings offer significant insights for developing policy solutions in environmental management in Jakarta aimed at mitigating ozone pollution.

Keywords: Ozone; industry; traffic congestion; green open spaces; regression analysis;

Introduction

Ground-level ozone (O₃) is a hazardous secondary pollutant formed by the photochemical reaction of precursors like Volatile Organic Compounds (VOCs), Carbon Monoxide (CO), and Nitrogen Oxides (NO_x). Unlike stratospheric O₃, which provides UV protection, tropospheric O₃ poses a significant risk to human health, potentially increasing morbidity and mortality through respiratory and cardiovascular diseases in the short term and causing long-term effects such as diminished lung function and increased cancer risk (Malinović-Milićević et al., 2021; Tang et al., 2020). The persistent O₃ concentration in Jakarta is primarily fueled by industrial growth and heavy traffic. Industrial activities are major sources of NO_x and VOCs, while motor vehicles emit CO and NO_x (David & Niculescu, 2021; Hasan Shahariar et al., 2022). These pollutants react under sunlight, escalating O₃ formation (Xie et al., 2023; Zhao et al., 2022). Despite the regulatory framework set by the government (e.g., Law No. 41/1999 on Air Pollution Control), high O₃ levels persist (Yulinawati & Brunner, 2024), suggesting suboptimal emissions management from these key sectors.

Conversely, Jakarta faces a challenge with the limited availability of Green Open Space (GOS), comprising only 5% of its total area—far below the required 30% standard – Law No. 26/2006 (DLH, 2023). GOS is crucial for air quality management, as plants effectively reduce pollutants, including O₃, through stomatal absorption and microbial degradation of VOCs in the rhizosphere (Ai et al., 2023; Venter et al., 2024). It is therefore imperative to conduct further research into the impact of industrial activities, traffic congestion and the presence of GOS on O₃ concentrations in Jakarta, in order to inform more effective environmental management policies. Given these complex interactions, ecological and environmental studies are vital for evidence-based policy formulation (Reichert et al., 2015). These models enable thorough examination of policy outcomes, reducing risks prior to execution (Rodrigues et al., 2024; Schmolke et al., 2010).

Although previous research predicted O₃ based on meteorological or NO₂ data, no study has specifically analyzed the combined influence of industrial activity, traffic congestion, and GOS proportions on O₃ concentrations in urban settings like Jakarta.

Therefore, this study aims to quantify the influence of industrial activities, traffic congestion, and the proportion of GOS on tropospheric O₃ concentrations in Jakarta. The findings are expected to offer novel, context-specific insights to inform air quality mitigation strategies, thereby providing a robust scientific basis for sustainable environmental policy and contributing to Sustainable Development Goal (SDG) 11 on sustainable cities and communities (United Nation, 2022).

Method

This study effectively utilized correlation analysis to pinpoint the robust association between O₃ concentration and three critical factors: the number of industries, traffic congestion, and GOS. Employing correlation to capture the reciprocal dependence between these phenomena (Schober et al., 2018), we computed the regression model parameters using the Ordinary Least Squares (OLS) method. To maximize the accuracy and reliability of the estimation findings, the data successfully underwent classical assumption tests, confirming normal distribution, the absence of multicollinearity, and homoscedasticity. The final model's explanatory power was meticulously assessed using comprehensive metrics, including R-squared, adjusted R-squared, RMSE, MAE, and MAPE. The adjusted R-squared coefficient specifically ensured that the model's high explanatory variation accurately accounts for the number of independent variables (Gujarati & Porter, 2015).

Result and Discussion

The Spearman correlation was employed in this study since the congestion proportion data did not follow a normal distribution. This value is crucial for understanding the strength of the relationship between each factor and the variation of O₃ concentration in the study area. The results in Figure 1(A) demonstrate a positive and significant correlation between O₃ and industry ($r = 0.55$, $p = 0.0000$), confirming hypothesis 1. This indicates that the increase in these two factors is aligned with the increase in O₃ concentration. The correlation analysis results of traffic congestion with O₃ in Figure 1(B) reveal a positive correlation ($r = 0.16$), in accordance with the hypothesized relationship set out in hypothesis 2. However, this correlation is not statistically significant ($p = 0.3142$), indicating that the evidence of this positive relationship is not sufficiently robust. In contrast, Figure 1(C) depicts a negative correlation between GOS and O₃ ($r = -0.32$), indicating that an increase in the proportion of GOS is associated with a reduction in the concentration of O₃ in the atmosphere. This finding substantiates hypothesis 3, which postulates a negative relationship between GOS and O₃.

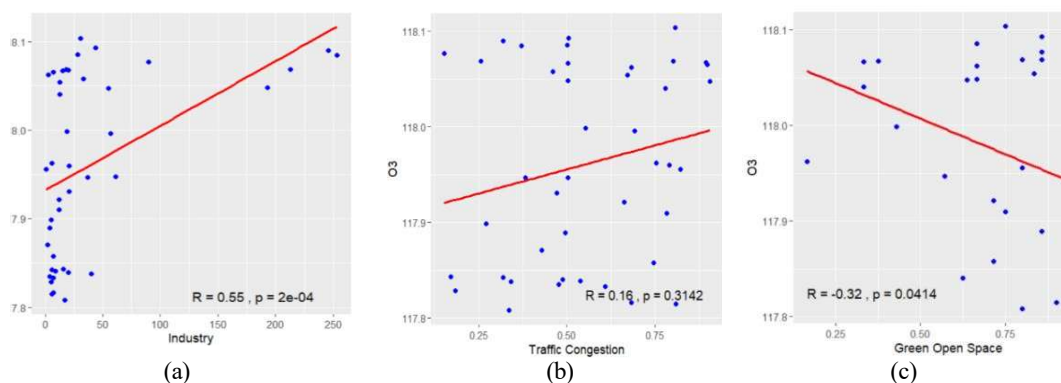


Figure 1. Correlation of tropospheric ozone concentrations with (a) industry, (b) traffic congestion, and (c) green open space (GOS).

The objective of the regression analysis conducted in this study is to elucidate the relationship between the concentration of O₃ and three independent variables: the number of industries, traffic congestion, and the proportion of GOS. The regression results are presented

Table 1. The results of the simultaneous significance testing yielded an F-test statistic value of 9.604 and a p-value of 0.0000, indicating the presence of at least one significant independent variable in the model. The partial test results also demonstrate that the intercept, number of industries, traffic congestion, and GOS exert a notable influence on tropospheric O₃ concentration. The regression model equation is presented in equation (1).

Table 1. Regression analysis result.

Variable	Slope Coefficient	SE	Sig.
Constant	117.9481	0.0744	0.0000**
Industry	0.0009	0.0002	0.0000**
Traffic Congestion	0.1439	0.0670	0.0382*
Green Open Space	-0.1296	0.0603	0.0382*

Asterisks denote significance: ** $p < 0.01$, * $p < 0.05$

$$O_{3i} = 117.9481 + 0.0009Industry_i + 0.1439Traffic_i - 0.1296OGS_i \quad (1)$$

The regression model was also subjected to evaluation using several established matrices. The R-squared value was 0.431, while the adjusted R-squared was 0.386. This indicates that approximately 43% of the variation in O₃ concentration could be attributed to the three variables. The remaining 57 per cent is not explained by the model, indicating that there are additional factors affecting O₃ concentrations beyond those included in the analysis. The RMSE value of 0.076 indicates that the model predictions are relatively accurate, with a small average prediction error. The MAE value of 0.061 and MAPE of 0.052 indicate that the prediction error is within a relatively low range. These results illustrate that the number of industries, traffic congestion, and GOS play a significant role in influencing O₃ concentrations. Specifically, high industrial activity and traffic can increase O₃ concentrations, while a high proportion of GOS can reduce O₃ concentrations.

Correlation analysis revealed that industrial expansion is a major source of O₃ precursors (NO_x and VOCs) and has a significant positive relationship with increasing O₃ concentrations (Lelieveld et al., 2015; Venter et al., 2024). Although Jakarta is globally known for its severe traffic congestion, the analysis found the positive correlation between traffic volume and O₃ concentration to be modest or statistically insignificant in certain models, suggesting the influence of additional contributing factors (Alexander Y. Bigazzi & Clifton, 2015; Kurniawan et al., 2025). Conversely, Green Open Space (GOS) demonstrated a significant negative correlation with O₃ levels, confirming its vital role in pollutant reduction through photosynthesis and absorption (Hasabi et al., 2024; Venter et al., 2024).

Regression results indicated that traffic congestion remains the most significant driver of increasing O₃ concentrations, aligning with the transport sector's status as a primary emitter in Jakarta. However, GOS provided the greatest impact on O₃ reduction. Given that the overall model explained less than 50% of the variance, future research must incorporate other established meteorological and chemical factors, such as NO₂ titration, UV index, and wind speed (Kurniawan et al., 2025). To mitigate O₃ pollution, policy recommendations emphasize three strategies: (1) implementing *green industry* concepts to curb industrial emissions; (2) rigorously enforcing traffic measures like Low Emission Zones and enhancing electric-powered public transport to reduce vehicular emissions; and (3) aggressively pursuing vertical green infrastructure given Jakarta's scarcity of GOS (only 5% of total area, far below the required 30%). Effective implementation of these strategies requires a comprehensive Penta-Helix collaborative model involving government, industry, academia, and the community.

Conclusion

This study successfully investigated the impact of industrial concentration, traffic congestion, and the proportion of GOS on O₃ levels in the Jakarta area. The findings confirm that both the number of industries and traffic congestion significantly increase O₃ concentrations, while GOS effectively reduces them. The regression model demonstrated substantial explanatory power, with an R² of 43 percent for the measured variables' contribution to O₃ variations. To address this environmental challenge, policymakers should prioritize reducing industrial emissions, enhancing

traffic management, and significantly expanding GOS within the city. Future research should focus on detailed spatial analyses for local-scale O₃ variations and long-term studies to monitor both concentration changes and the effectiveness of new policies.

Acknowledgment

We extend our gratitude to Rafif Hasabi for his crucial support in the completion of this essay. All authors disclose no conflicting financial interests.

References

- Ai, H., Zhang, X., & Zhou, Z. (2023). The impact of greenspace on air pollution: Empirical evidence from China. *Ecological Indicators*, 146(November 2022), 109881. <https://doi.org/10.1016/j.ecolind.2023.109881>
- Alexander Y. Bigazzi, M. A. F., & Clifton, K. J. (2015). Traffic Congestion and Air Pollution Exposure for Motorists: Comparing Exposure Duration and Intensity. *International Journal of Sustainable Transportation*, 9(7), 443–456. <https://doi.org/10.1080/15568318.2013.805345>
- David, E., & Niculescu, V. C. (2021). Volatile organic compounds (Vocs) as environmental pollutants: Occurrence and mitigation using nanomaterials. *International Journal of Environmental Research and Public Health*, 18(24). <https://doi.org/10.3390/ijerph182413147>
- DLH. (2023). *DKI Jakarta Green Open Space Data (In Indonesian)*. <https://data.jakarta.go.id/dataset/ruangterbukahijaudkijakarta>
- Gujarati, D. N., & Porter, D. C. (2015). *Basic Econometric* (5th ed.). New York: McGraw Hill.
- Hasabi, R., Kurniawan, R., Sugiarto, Wahyuni, R. N. T., & Nurmawati, E. (2024). Urban traffic congestion and its association with gas station density: insights from Google Maps data. *Indonesian Journal of Electrical Engineering and Computer Science*, 35(3), 1618–1626. <https://doi.org/10.11591/ijeecs.v35.i3.pp1618-1626>
- Hasan Shahariar, G. M., Sajjad, M., Suara, K. A., Jahirul, M. I., Chu-Van, T., Ristovski, Z., Brown, R. J., & Bodisco, T. A. (2022). On-road CO₂ and NO_x emissions of a diesel vehicle in urban traffic. *Transportation Research Part D: Transport and Environment*, 107, 103326. <https://doi.org/10.1016/J.TRD.2022.103326>
- Kurniawan, R., Hasabi, R., Wongsonadi, S. K., Gio, P. U., Purwanto, A., & Sumargo, B. (2025). Examining the Influence of Congestion, Industry, and Green Open Space on Air Quality Vulnerability in Towards Green Development in Jakarta. *Innovation and Green Development*, 4(March), 1–14. <https://doi.org/10.1016/j.igd.2025.100247>
- Lelieveld, J., Evans, J. S., Fnais, M., Giannadaki, D., & Pozzer, A. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*, 525(7569), 367–371. <https://doi.org/10.1038/nature15371>
- Malinović-Miličević, S., Vyklyuk, Y., Stanojević, G., Radovanović, M. M., Doljak, D., & Čurčić, N. B. (2021). Prediction of tropospheric ozone concentration using artificial neural networks at traffic and background urban locations in Novi Sad, Serbia. *Environmental Monitoring and Assessment*, 193(2), 1–13. <https://doi.org/10.1007/s10661-020-08821-1>
- Reichert, P., Langhans, S. D., Lienert, J., & Schuwirth, N. (2015). The conceptual foundation of environmental decision support. *Journal of Environmental Management*, 154, 316–332. <https://doi.org/10.1016/j.jenvman.2015.01.053>
- Rodrigues, V., Augusto, B., Oliveira, K., Ascenso, A., Rafael, S., Nascimento, D., & Miranda, A. I. (2024). Setting up a CFD model to evaluate the impact of green infrastructures on local air quality. *Air Quality, Atmosphere and Health*, 0123456789. <https://doi.org/10.1007/s11869-024-01567-6>
- Schmolke, A., Thorbek, P., DeAngelis, D. L., & Grimm, V. (2010). Ecological models supporting environmental decision making: A strategy for the future. *Trends in Ecology and Evolution*, 25(8), 479–486. <https://doi.org/10.1016/j.tree.2010.05.001>

- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia*, 126(5). https://journals.lww.com/anesthesia-analgesia/fulltext/2018/05000/correlation_coefficients_appropriate_use_and.50.aspx
- Tang, X., Gao, X., Li, C., Zhou, Q., Ren, C., & Feng, Z. (2020). Study on spatiotemporal distribution of airborne ozone pollution in subtropical region considering socioeconomic driving impacts: A case study in Guangzhou, China. *Sustainable Cities and Society*, 54, 101989. <https://doi.org/10.1016/j.scs.2019.101989>
- United Nation. (2022). *The Sustainable Development Goals Report 2022*. New York: United Nation.
- Venter, Z. S., Hassani, A., Stange, E., Schneider, P., & Castell, N. (2024). Reassessing the role of urban green space in air pollution control. *Proceedings of the National Academy of Sciences*, 121(6), e2306200121. <https://doi.org/10.1073/pnas.2306200121>
- Xie, Q., Tham, Y. J., Yu, X., Wang, Z., Ling, Z., Wang, X., Guo, H., & Wang, T. (2023). Seasonal variations of O₃ formation mechanism and atmospheric photochemical reactivity during severe high O₃ pollution episodes in the Pearl River Delta region. *Atmospheric Environment*, 309(November 2022), 119918. <https://doi.org/10.1016/j.atmosenv.2023.119918>
- Yulinawati, H., & Brunner, I. M. I. M. (2024). *Maximum Hourly and Daily Concentration Patterns of Urban Jakarta Tropospheric Ozone*. IX(1).
- Zhao, Y., Li, Y., Kumar, A., Ying, Q., Vandenberghe, F., & Kleeman, M. J. (2022). Separately resolving NO_x and VOC contributions to ozone formation. *Atmospheric Environment*, 285(June), 119224. <https://doi.org/10.1016/j.atmosenv.2022.119224>

Scope : Environment

Article ID : 117

ANALYSIS OF PHYSICAL WORK ENVIRONMENT IN NICKEL MINING INDUSTRY: A CASE STUDY OF PT X

Nurcitra Rehulina Br Ginting*, I Made Astra, and Dwi Atmanto

Environmental Management, Jakarta State University, Jakarta, Indonesia

Email: *nurcitra.rehulina@mhs.unj.ac.id

Abstract

This study evaluates the physical working environment conditions at PT X, a nickel mining contractor operating in North Morowali Regency. Three parameters were analyzed: lighting, noise, and working climate in the Office, Workshop, and PIT areas. Measurements were conducted in accordance with national standards (SNI) using calibrated instruments. The results show that all parameters are below the Threshold Limit Value (TLV) stipulated in the Minister of Manpower Regulation No. 5 of 2018, indicating that the overall working conditions are safe for workers. However, the lighting intensity in the Office area was 106 Lux, which does not meet the minimum lighting standard. This finding highlights the need for improvements in the lighting system and regular monitoring of physical environmental factors to ensure safety, comfort, and productivity. The study emphasizes the importance of implementing sustainable work environment management to support occupational safety and health in the mining industry.

Keywords: Physical work environment, lighting, noise, working climate, threshold limit value (TLV)

Introduction

The work environment is a crucial element within the organizational ecosystem that plays a significant role in determining how employees carry out their tasks (Fauzi & Aminuddin, 2022). It encompasses various aspects surrounding employees that can influence their performance and work effectiveness (Anggraini & Febrian, 2025). One of the main aspects is the physical work environment, which has both direct and indirect impacts on work activities (Maulidiyah & Ilahi, 2020). A well-designed and supportive physical environment not only enhances comfort but also boosts productivity and strengthens social relationships within the organization (Kearney et al., 2023). This condition promotes job satisfaction, which in turn positively impacts employee motivation and performance (Fitriyani et al., 2024; Agus & Marpaung, 2023). Physical factors play an essential role in shaping the quality of the work environment, influencing employees' productivity, health, well-being, and job satisfaction (Setyadi et al., 2015, as cited in Febriyani, 2024). Conversely, an unfavorable work environment may require more effort and time, thereby reducing productivity (Suryaputra, 2023). According to Sowmya and Panchanatham (2011, as cited in Alam, 2020), creating a comfortable work environment requires attention to several physical aspects, such as workspace layout, lighting, noise control, and overall comfort, all of which can enhance employee morale and foster a sense of belonging in the workplace. Managing these physical aspects is therefore an essential factor in supporting work performance (Setiani et al., 2022).

In the mining industry, physical work environment factors are crucial due to the high level of occupational risk. PT X, a nickel mining contractor in North Morowali, operates in areas involving heavy equipment and high-risk field activities, making the physical work environment essential for maintaining worker safety and productivity. This study analyzes noise, temperature, and lighting conditions at PT X. The findings are expected to provide valuable insights for

company management to improve working conditions and foster a safe, comfortable, and productive work environment.

Method

The research was conducted at the nickel mining company PT X. This study was an observational study of the physical work environment, with quantitative data collection using direct reading measurements of physical factors in the work environment. Data collection was carried out in potential work areas such as the Office, Workshop, and PIT. The direct reading instruments used were specialized tools for measuring lighting, noise, and working climate at predetermined locations using calibrated Lux meters, Heatstress Monitoring, and Sound Level Meters. Measurement standards refer to SNI 7062-2019 for lighting, SNI 7231:2009 for noise, and SNI 7061-2019 for working climate. The collected data consisted of direct measurements of workers' physical work environment conditions while performing their work. The obtained data were then compared with the Threshold Limit Values (TLV) stipulated in Ministerial Regulation No. 5 of 2018 to assess the suitability of the physical environmental conditions. his method provides accurate data to enhance safety, comfort, and productivity in mining.

Result and Discussion

This study aims to analyze the extent to which the physical work environment at PT X supports workers in carrying out their duties. The mining industry faces specific challenges in workspace management, particularly regarding physical factors that can impact worker safety, comfort, and productivity (Azizah & Prahiawan, 2024). Worker productivity is influenced by work comfort factors, which are determined by environmental factors (Saefullah & Basrowi, 2022). The analysis focused on three main physical factors: lighting, noise, and working climate conditions, to provide a snapshot of actual conditions in the field. The results of the measurements in the Office area are presented in the following table.

Table 1. Measurement of Physical Work Environment in the Office Area

Physical Work Environment	Measurement results	TLV/Standar	Remarks
Light	106 Lux	300 Lux	Does not meets the standard
Noise	67 dBA	85 dBA	Below the threshold limit
Work Climate	22,1°C	31°C	Below the threshold limit

Table 2. Measurement of Physical Work Environment in the Workshop Area

Physical Work Environment	Measurement results	TLV/Standar	Remarks
Light	337 Lux	300 Lux	Meets the standard
Noise	76,3 dBA	85 dBA	Below the threshold limit
Work Climate	28°C	28°C	Below the threshold limit

Table 3. Measurement of Physical Work Environment in the PIT Area

Physical Work Environment	Measurement results	TLV/Standar	Remarks
Light	196 Lux	50 Lux	Meets the standard
Noise	79,5 dBA	85 dBA	Below the threshold limit
Work Climate	26°C	31°C	Below the threshold limit

The results of measurements of the physical work environment in three areas (Office, Workshop, and PIT) indicate that, in general, all parameters are still below the Threshold Limit Value (TLV) based on Ministerial Regulation No. 5 of 2018, so they can be categorized as safe for workers. However, in the Office area, the lighting intensity was 106 Lux, which does not meet the minimum standard of 300 Lux. This condition indicates the need to improve lighting quality to maintain visual comfort and work productivity, especially for administrative activities that require high accuracy. An optimal lighting system not only enhances work efficiency but also has a positive impact on employees' motivation as well as their physical and psychological health. According to research conducted by Abidin et al. (2025), appropriate lighting has been proven to increase employee performance by up to 10.05% highlighting its importance in creating a productive and comfortable work environment. In contrast, the Workshop and PIT areas showed good lighting conditions, at 337 Lux and 196 Lux, respectively, which met lighting standards. Based on the results of the analysis of the lighting measurement data that has been carried out, lighting control is needed, which must be carried out by increasing the lighting. The amount of light required for each type of work varies. Work areas require a sufficient level of visual comfort so workers can perform their tasks effectively and productively (Noya, 2024). Good lighting helps workers see clearly and comfortably, allowing them to work optimally. This impacts increased productivity and work efficiency and reduces the likelihood of work errors (Pujianti & Djunaidi, 2022). Noise levels in all areas are below the TLV 85 dBA, between 67 and 79.5 dBA, which is still within the safe category, although the Workshop and PIT areas have higher values due to the activity of machinery and heavy equipment. The work climate ranges from 22.1°C to 28°C, still within the limit, indicating comfortable thermal conditions without excessive heat stress.

Overall, these results indicate that the quality of the physical work environment at the research location is still considered safe and under control, but lighting improvements in the office area are needed as a step to improve the quality of the work environment. Efforts to improve lighting through improving the layout of the room, adding natural and artificial light sources, replacing dead lamps, and increasing the intensity of lighting with lamps with higher capacity, and regular evaluations can improve the quality of the work environment (Niland & Elam, 2022). In addition, it is important to measure lighting levels in all work areas to ensure compliance with applicable standards. Furthermore, a well-designed physical work environment can strengthen organizational culture and enhance overall performance (Sapiah Abdul Hamed et al., 2024). Moreover, poor physical conditions can cause both direct and indirect health problems due to negative environmental factors (Adi, 2024). Regular monitoring of lighting, noise, and work climate plays a crucial role in maintaining the balance between productivity and environmental sustainability. This effort also helps create a comfortable work environment while supporting overall organizational performance (Oyedeki, Ko, & Lee, 2025).

Conclusion

The study results indicate that the physical work environment at PT X is generally safe and complies with Minister of Manpower Regulation No. 5 of 2018. Noise and work climate parameters are below the Threshold Limit Value (TLV), while most lighting meets the required standards, except in the office area, which remains below 300 Lux and requires improvement. Implementing proper work environment management helps maintain workers' health and safety while enhancing productivity and organizational performance (Shaari et al., 2022). This study emphasizes the importance of controlling the physical aspects of the work environment to support sustainable environmental management in the mining sector.

Acknowledgment

The author thanks all who supported this research, especially the lecturers of the Postgraduate Environmental Management Program, Universitas Negeri Jakarta.

References

- Abdul Hamed, S., Mohd Hussain, M. R., Md Jani, H. H., Shah Sabri, S. S., & Rusli, N. (2023). The impacts of physical workplace environment (PWE) on employees productivity. *International Journal of Business and Technology Management*, 5(4), 369–376. <https://doi.org/10.55057/ijbtm.2023.5.4.33>
- Abidin, F. M., Diana, S., & Katiningrum, E. D. (2025). The influence of physical work environment factors on the performance of employees of the Mojokerto Regency Health Office. *International Journal of Nursing and Midwifery Science (IJNMS)*, 9(2), 187–194. <https://doi.org/10.29082/IJNMS/2025/Vol9/Iss2/705>
- Anas Firman Adi. (2024). Influence of physical work environment factors, equipment and materials on occupational health and safety In Ahass city workshop poor. *International Journal of Economics, Management and Accounting*, 1(2), 97–112. <https://doi.org/10.61132/ijema.v1i2.50>
- Agus, Y. F., & Marpaung, N. (2023). The influence of compensation, work environment and work discipline on employee performance at PT. Bank Sumut Branch of Sipirok. *Current Advanced Research on Sharia Finance and Economic Worldwide*, 2(2), 332–347. <https://doi.org/10.55047/cashflow.v2i2.544>
- Alam, S. (2020). The role of physical work environment and work stress in affecting employee performance. *International Journal of Multicultural and Multireligious Understanding*, 7(8), 529–535. <https://doi.org/10.18415/ijmmu.v7i8.1962>
- Anggraini, R., & Febrian, W. D. (2025). The effect of work discipline, physical work environment and employee professionalism on employee performance. *IJAM: International Journal of Advanced Multidisciplinary*, 4(1). <https://doi.org/10.38035/ijam.v4i1>
- Azizah, J. N., & Prahiawan, W. (2024). Systematic literature review: The effect of work environment and work supervision on employee performance. *Jurnal Administrasi Bisnis Terapan*, 6(2). <https://scholarhub.ui.ac.id/jabt/>
- Febriyani, M., & Putri, R. K. (2024). The influence of the physical work environment and work discipline on employee performance at the Tegal district health office. *Indonesian Interdisciplinary Journal of Sharia Economics (IIJSE)*, 7(3), 4789–4811. <https://doi.org/10.31538/ijse.v7i3.5152>
- Fitriayani, I., Krisnandi, H., & Digidowiseiso, K. (2024). The influence of workload, work motivation, and physical work environment on employee performance. *International Journal of Social Service and Research*, 4(2). <https://doi.org/10.46799/ijssr.v4i02.697>
- Fauzi, & Aminuddin. (2022). The Effect of Physical Work Environment and Communication on Employee Job Satisfaction in PT. Razza Prima Trafo Medan. *International Journal of Science, Technology & Management*, 3(2), 299–310. <https://doi.org/10.46729/ijstm.v3i2.467>
- Kearney T, Coughlan J, Kennedy A (2023), "The influence of the physical work environment on retail employees". *Journal of Services Marketing*, Vol. 37 No. 6 pp. 719–731, <https://doi.org/10.1108/JSM-04-2022-0130>
- Maulidiyah, N. N., & Ilahi, R. R. (2020). The impact of physical work environment on employee performance by job satisfaction as mediator. *International Journal of Research in Human Resource Management*, 2(1), 1–3. <https://doi.org/10.33545/26633213.2020.v2.i1a.29>
- Noya, J. (2024). Physical and non-physical work environment on employee performance. *Asian Journal of Management Entrepreneurship and Social Science*, 4(2). <https://ajmesc.com/index.php/ajmesc>

- Niland, J., & Elam, L. A. (2022). *Fundamentals of industrial hygiene* (7th ed.). Itasca, IL: National Safety Council Press.
- Oyededeji, B. A., Ko, Y. H., & Lee, S. (2025). Physical work environments: An integrative review and agenda for future research. *Journal of Management*, 51(6), 2589–2626. <https://doi.org/10.1177/01492063251315703>
- Pujanti, P., & Djunaidi, Z. (2022). Evaluation of the physical work environment of miners in Kutai Kartanegara, East Kalimantan. *The Indonesian Journal of Occupational Safety and Health*, 11(Special Issue), 39–47. <https://doi.org/10.20473/ijosh.v11SI.2022.39-47>
- Peraturan Menteri Ketenagakerjaan No.5 Tahun 2018 tentang Keselamatan dan Kesehatan Kerja (K3) Lingkungan Kerja
- Saefullah, M., & Basrowi. (2022). Dampak lingkungan kerja fisik terhadap kinerja dan kepuasan karyawan bagian produksi. *Jurnal Bina Bangsa Ekonomika*, 15(2). <https://doi.org/10.46306/jbbe.v15i2>
- Setiani, S., Sari, R. K., Munfarikha, A., & Safitri, R. (2022). Work ethos as mediator of the influence of human relations and physical work environment on employee performance. *Asian Journal of Economics, Business and Accounting*, 22(23), 297–304. <https://doi.org/10.9734/AJEBA/2022/v22i238274>
- Shaari, R., Sarip, A., & Ramadhinda, S. (2022). A study of the influence of physical work environments on employee performance. *International Journal of Academic Research in Business and Social Sciences*, 12(12). <https://doi.org/10.6007/IJARBSS/v12-i12/15975>
- Suryaputra, N. (2023). Impact analysis of work environment mediated by job satisfaction on employee performance (Case study Asuransi Siap). *International Journal of Current Science Research and Review*, 6(4), 3312–3318. <https://doi.org/10.47191/ijcsrr/V6-i4-41>

MOVING BED BIOFILM REACTOR (MBBR) AS AN ADVANCED BIOLOGICAL TECHNOLOGY FOR SUSTAINABLE WASTEWATER TREATMENT

Bheni David*, Cahyadi Setiawan, and Dwi Atmanto

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *bheni.david@mhs.unj.ac.id

Abstract

The increasing population and rapid industrial development have led to greater demand for clean water and higher volumes of wastewater requiring proper treatment before discharge into the environment. The Moving Bed Biofilm Reactor (MBBR) is an advanced biological wastewater treatment process that combines the advantages of activated sludge and attached- growth systems. This technology utilizes free-moving carriers with a large surface area for biofilm growth, enabling high biomass retention, stable pollutant removal, and compact reactor design. Literature studies show that MBBR achieves more than 85% removal efficiency for BOD and COD, and consistent nitrification–denitrification under optimal conditions. Due to its flexibility, operational simplicity, and low maintenance cost, MBBR represents a promising and sustainable solution for both domestic and industrial wastewater treatment.

Keywords: MBBR, biofilm, wastewater treatment, BOD, COD

Introduction

Industrial wastewater management has become a crucial aspect of sustainable development, given the increasing pressure from industrial growth and environmental regulations. Various industries such as textile, pulp and paper, food and beverage, and petrochemical sectors produce complex effluents containing organic matter, heavy metals, and toxic compounds. If inadequately treated, these pollutants can degrade water quality, harm aquatic ecosystems, and pose health risks. Conventional biological processes like the Activated Sludge Process (ASP), Sequencing Batch Reactor (SBR), and Membrane Bioreactor (MBR) have been applied widely. However, such systems often require large footprints, intensive energy, and high operational costs, and they show reduced efficiency under variable organic loading.

To address these limitations, biofilm-based technologies have gained attention for their robustness and compactness. Among them, the Moving Bed Biofilm Reactor (MBBR) represents a hybrid system combining suspended and attached-growth mechanisms. Its carriers allow higher microbial density and stable pollutant removal, making it effective even under fluctuating conditions. This paper reviews the principles, performance, and applications of MBBR technology for wastewater treatment. The discussion focuses on pollutant removal efficiency, operational factors, and comparative advantages over conventional systems.

Method

This study employed a Systematic Literature Review (SLR) approach based on Kitchenham and Charters (2007) and guided by the PRISMA framework. The review focused on studies from 2013 to 2024 discussing MBBR performance in wastewater treatment. Literature

was retrieved from Scopus, ScienceDirect, Web of Science, and Google Scholar using keywords such as “Moving Bed Biofilm Reactor,” “industrial wastewater,” and “MBBR performance.” Only peer-reviewed papers providing quantitative removal data were included. Extracted information covered wastewater type, operational parameters such as hydraulic retention time (HRT), filling ratio, temperature, carrier type, and pollutant removal efficiency. Data were analyzed descriptively to identify trends, operational factors, and technology gaps in MBBR application. The method composition accounts for approximately ten percent of the total paper content.

Result and Discussion

Studies show that MBBR demonstrates excellent pollutant removal capacity. Chemical oxygen demand (COD) removal generally ranges between 76–88%, while biochemical oxygen demand (BOD) removal exceeds 90% under optimal conditions (Kumar et al., 2018; Rahman et al., 2019). The system’s efficiency is attributed to the high specific surface area of carriers and the stability of attached biofilm communities. In pharmaceutical wastewater, MBBR achieved 82% COD removal (Zhang & Li, 2020), while for petrochemical wastewater, phenol removal reached 68% (Smith et al., 2021). Similar performance was also observed in textile and pulp industries (Tang et al., 2017; Oliveira et al., 2014).

Operational factors such as carrier material, filling ratio, hydraulic retention time, and biofilm thickness significantly affect MBBR efficiency. Carriers with higher surface area, such as K5 media, enhance biofilm growth and stability (Rahman et al., 2019). Optimum HRTs between 6 and 12 hours ensure sufficient contact and microbial activity, while excessive biofilm thickness may hinder oxygen and nutrient diffusion, reducing removal efficiency (Banti et al., 2023).

Compared to conventional activated sludge systems, MBBR offers several advantages. The system operates without the need for sludge recirculation, maintains high stability under variable loads, requires smaller space, and generates less sludge, resulting in lower operational costs. Despite its advantages, MBBR still faces challenges such as biofilm detachment due to shear stress, potential clogging at high organic loading, and carrier material cost. Furthermore, its efficiency may decline when treating highly toxic or saline wastewater (Zhao et al., 2019).

Recent trends in research have focused on hybrid MBBR configurations, integrating it with Membrane Bioreactors (MBR), Anaerobic Digestion, and Advanced Oxidation Processes (AOPs) to enhance nutrient and micropollutant removal (Ahammad & Dewil, 2020; Li & Chen, 2022). The development of 3D-printed biocarriers and sponge-based reactors also shows promising improvements in performance and durability (Chalipa et al., 2024; Banti et al., 2023). Overall, MBBR continues to evolve as a highly adaptable technology for modern wastewater treatment systems, supporting sustainability and compliance with stricter discharge regulations.

Conclusion

The Moving Bed Biofilm Reactor (MBBR) offers a highly efficient and flexible solution for sustainable wastewater treatment. Its hybrid mechanism ensures high organic and nutrient removal, compact footprint, and operational stability. Despite limitations such as carrier cost and biofilm detachment, MBBR remains a promising technology for future applications. Further studies should focus on biofilm longevity, hybrid integrations, and life-cycle assessments to enhance industrial-scale optimization.

Acknowledgment

The authors would like to express their gratitude to the Environmental Management Study Program, Postgraduate Program, Universitas Negeri Jakarta, for their valuable support in conducting this research.

References

- Ahammad, S. Z., & Dewil, R. (2020). Recent advances in hybrid MBBR technology for wastewater treatment: A review. *Applied Water Science*, 10(6), 152. <https://doi.org/10.1007/s13201-022-01662-y>
- Andini, R., Prasetyo, H., & Nugroho, A. (2022). Performance of moving bed biofilm reactor (MBBR) in treating mixed domestic and industrial wastewater. *Journal of Environmental Engineering and Sustainable Technology*, 9(2), 145–154.
- Banti, D. C., Samaras, P., Chioti, A. G., Mitsopoulos, A., Tsangas, M., Zorpas, A., & Sfetsas, T. (2023). Improvement of MBBR performance by the addition of 3D-printed biocarriers fabricated with 13X and bentonite. *Resources*, 12(7), 81. <https://doi.org/10.3390/resources12070081>
- Chalipa, Z., Panahi, H. A., & Balarak, D. (2024). Performance evaluation of a new sponge-based moving bed biofilm reactor for the removal of pharmaceutical pollutants from real wastewater. *Scientific Reports*, 14(1), 5123. <https://doi.org/10.1038/s41598-024-64442-5>
- Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering (Technical Report EBSE-2007-01). Keele University and University of Durham.
- Kumar, P., Singh, R., & Verma, S. (2018). Evaluation of moving bed biofilm reactor for industrial wastewater treatment: A pilot-scale study. *Environmental Technology & Innovation*, 12, 198–207. <https://doi.org/10.1016/j.eti.2018.02.007>
- Li, X., & Chen, Y. (2022). Biofilm-based processes for sustainable industrial wastewater treatment: A comprehensive review. *Materials Advances*, 3(12), 4821–4834. <https://doi.org/10.1039/d2ma00945e>
- Liu, J., Zhou, J., Xu, N., He, A., Xin, F., Ma, J., Fang, Y., Zhang, W., Liu, S., Jiang, M., & Dong, W. (2019). Performance evaluation of a lab-scale moving bed biofilm reactor (MBBR) using polyethylene as support material in the treatment of wastewater contaminated with terephthalic acid. *Chemosphere*, 227, 117–123. <https://doi.org/10.1016/j.chemosphere.2019.03.186>
- Metcalf & Eddy. (2014). *Wastewater engineering: Treatment and resource recovery* (5th ed.). McGraw-Hill Education.
- Oliveira, D. V. M., Rabelo, M. D., & Nariyoshi, Y. N. (2014). Evaluation of a MBBR (Moving Bed Biofilm Reactor) pilot plant for treatment of pulp and paper mill wastewater. *International Journal of Environmental Monitoring and Analysis*, 2(4), 220–225. <https://doi.org/10.11648/j.ijema.20140204.15>
- Pratap, V. (2024). Optimization of moving bed biofilm reactors for the treatment of municipal wastewater: Impact of media type, filling ratio, and HRT. *Environmental Research*, 241, 117560. <https://doi.org/10.1016/j.envres.2023.117560>
- Rahman, M., Sultana, T., & Chowdhury, S. (2019). Comparative study of K1 and K5 media in MBBR process for textile wastewater treatment. *Journal of Water Process Engineering*, 31, 100–112. <https://doi.org/10.1016/j.jwpe.2019.100112>
- Rusten, B., Eikebrokk, B., Ulgenes, Y., & Lygren, E. (2006). Design and operations of the Kaldnes moving bed biofilm reactors. *Aquacultural Engineering*, 34(3), 322–331. <https://doi.org/10.1016/j.aquaeng.2005.04.002>
- Smith, J., Lee, C., & Brown, D. (2021). Application of MBBR for petrochemical wastewater treatment: Challenges and perspectives. *Journal of Hazardous Materials*, 412, 125–135. <https://doi.org/10.1016/j.jhazmat.2021.125135>

- Tang, K., Ooi, G. T. H., Litty, K., Sundmark, K., Kaarsholm, K. M. S., Bester, K., & Andersen, H. R. (2017). Removal of pharmaceuticals in conventionally treated wastewater by a polishing moving bed biofilm reactor (MBBR) with intermittent feeding. *Bioresource Technology*, 236, 77–86. <https://doi.org/10.1016/j.biortech.2017.03.159>
- Zhang, Q., Li, X., & Liu, H. (2024). MBBR start-up with heterotrophic nitrification–aerobic denitrification (HN–AD) bacteria inoculation under low C/N conditions. *Journal of Water Process Engineering*, 75, 104786. <https://doi.org/10.1016/j.jwpe.2024.104786>
- Zhang, Y., & Li, H. (2020). Treatment of pharmaceutical wastewater using moving bed biofilm reactor: Performance and biofilm dynamics. *Bioresource Technology*, 302, 122133. <https://doi.org/10.1016/j.biortech.2020.122133>
- Zhao, Y., Wang, S., & Zhang, J. (2019). Influence of carrier filling ratio on the advanced nitrogen removal from wastewater treatment plant effluent by denitrifying MBBR. *International Journal of Environmental Research and Public Health*, 16(18), 3244. <https://doi.org/10.3390/ijerph16183244>
- Zhou, J., Zhang, F., & Li, X. (2019). Startup performance of MBBR treating food industry effluent under different carrier filling ratios. *Water Science and Technology*, 80(6), 1109–1119. <https://doi.org/10.2166/wst.2019.382>
- Abdullah, N., Hashim, N. H. F., Rahman, N. A., & Anuar, A. N. (2023). Integration of moving bed biofilm reactor (MBBR) and constructed wetland for sustainable municipal wastewater treatment. *Journal of Environmental Chemical Engineering*, 11(6), 110087. <https://doi.org/10.1016/j.jece.2023.110087>

SYSTEM DYNAMICS MODELLING OF PUBLIC TRANSPORTATION AND ENERGY TRANSITION IN JAKARTA'S SMART CITY DEVELOPMENT

Danang Pratomo*, Eliana Sari, Bagus Sumargo, and Nadiroh Azizah

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *danang.pratomo@mhs.unj.ac.id

Abstrak

The transformation of Jakarta's public transportation system represents a key pathway toward achieving smart city objectives and low-carbon urban development. This study develops a conceptual System Dynamics modelling framework to explore the interconnections between transportation infrastructure, energy transition, carbon emissions, and smart governance. Using literature-based system mapping, causal feedback loops are constructed to represent how policy, energy use, and citizen participation interact dynamically. The conceptual simulation suggests that enhanced investment in low-emission transportation and smart infrastructure significantly supports emission reduction and sustainability performance. The findings highlight the role of integrated policy, data-driven governance, and public participation as reinforcing factors in achieving Jakarta's smart and sustainable city agenda.

Keywords: System Dynamics, Conceptual Modelling, Energy Transition, Public Transportation, Smart City

Introduction

The acceleration of urbanization in Jakarta has led to increasing challenges in mobility, environmental quality, and energy use. According to Bappenas (2023), transportation contributes over 40% of total carbon emissions in the capital region, making it a critical sector for climate mitigation and energy transition. At the same time, the Jakarta Smart City program aims to integrate data-driven governance, sustainable transport, and citizen-centric services to achieve the national vision of low-carbon development (Setiawan et al., 2023).

Globally, the integration of smart city and sustainable mobility strategies has gained attention as part of the broader transition toward net-zero cities (Zhang et al., 2022; Geels, 2021).

Studies in Seoul, Singapore, and Tokyo demonstrate that integrating public transport electrification with digital governance can enhance resource efficiency while reducing emissions (Wang et al., 2022). However, in developing cities like Jakarta, fragmented policies, limited energy infrastructure, and social inequalities hinder such integration (Nurhadi & Suryani, 2021).

This research aims to conceptualize a System Dynamics modelling framework that links public transportation development, energy transition, and smart city indicators. Unlike static policy analyses, System Dynamics (SD) enables the exploration of complex feedback relationships, policy delays, and emergent behaviors (Sterman, 2000). The study's contribution is a theoretical model structure that helps policymakers identify leverage points for accelerating sustainable transport and smart governance synergy in Jakarta.

Method

This study adopts a conceptual System Dynamics modelling approach, emphasizing structural representation and qualitative simulation over empirical computation. The research framework follows four stages adapted from Forrester (1961) and Sterman (2000):

1. Problem Identification. Review of urban transport and energy transition challenges in Jakarta through secondary data and scientific literature.
2. System Conceptualization. Development of causal loop diagrams (CLDs) illustrating feedback relationships among variables: transport policy, energy consumption, emissions, smart infrastructure, and public participation.
3. Model Formulation. Construction of reinforcing (R) and balancing (B) feedback loops to describe dynamic behavior qualitatively.
4. Scenario Conceptualization. Identification of potential policy leverage points (e.g., renewable energy adoption, electric mobility, and participatory governance).

Although no quantitative simulation is conducted, the conceptual model is developed to ensure structural validity, serving as a prototype for future dynamic simulation using tools such as *Vensim* or *Stella* (Richardson, 2013). The approach ensures interpretive coherence between variables within the smart city and energy transition subsystems.

Result and Discussion

1. Conceptual Model Overview

The resulting Conceptual System Dynamics Model consists of three interacting subsystems:

1. Transportation–Emission Loop (B1): Increased public transport investment reduces private vehicle usage, lowering total emissions and fossil fuel dependency.
2. Energy Transition Loop (R1): Renewable-powered transport systems enhance environmental quality, encouraging further policy and budget reinforcement.
3. Smart Governance Loop (R2): Enhanced digital data fosters improved policy feedback, increased citizen trust, and more effective participatory urban governance.

The interconnections among these loops reveal reinforcing dynamics between energy transition and smart governance, moderated by institutional coordination and community engagement. Policy inconsistency or slow data integration functions as a balancing loop, potentially delaying the realization of environmental benefits.

2. Policy Integration and Feedback Dynamics

From a systemic perspective, the success of Jakarta's smart mobility transition depends on interlinked feedback among policy design, energy efficiency, and citizen behavior. Past research has shown that feedback loops between infrastructure investment and behavioral change are often overlooked in conventional planning (Levin et al., 2022). Policy inertia or fragmented institutional responsibilities may generate time delays that weaken emission reduction outcomes.

Effective integration requires aligning transport electrification, renewable energy supply, and smart data management. For example, synchronizing bus electrification programs with the national renewable energy roadmap (ESDM, 2023) can lower the carbon intensity of the transport sector by up to 25% (IEA, 2022). Smart city platforms equipped with real-time emission tracking and open-data dashboards also enhance adaptive governance (Gupta & Pardo, 2021).

3. Smart City Indicators and System Leverage

Incorporating energy transition variables into Jakarta's smart city framework enhance multiple sustainability indicators: environmental performance, boosts energy efficiency, and fosters citizen participation. Conceptual simulation reveals that a higher renewable energy share produces

nonlinear emission reductions—an emergent property typical of SD models (Sterman, 2000).

Cross-case studies in Seoul and Singapore demonstrate that co-developing digital governance, sustainable transport, and participatory policy mechanisms yields synergistic outcomes for low-carbon urban systems (Yoon et al., 2022; Chen et al., 2023). Thus, the conceptual SD model highlights how feedback-driven policy coordination can amplify systemic sustainability outcomes in Jakarta.

Conclusion

This paper presents a conceptual System Dynamics modelling framework illustrating how transportation policy, energy transition, and smart city governance interact in shaping Jakarta's sustainable urban transformation. The model identifies reinforcing loops among renewable energy adoption, emission reduction, and smart governance as key enablers for sustainability. Conversely, fragmented institutional structures and limited data integration act as balancing constraints. The study concludes that integrated planning, data-driven governance, and participatory frameworks are critical leverage points for Jakarta's transition toward a low-carbon smart city. Future research should extend this conceptual framework into quantitative SD simulation to evaluate long-term policy outcomes.

Acknowledgment

The authors express gratitude to Universitas Negeri Jakarta for academic support and to the Jakarta Smart City Unit for providing access to policy documents and secondary data that informed this conceptual study.

References

- Bappenas. (2023). Indonesia Low Carbon Development Initiative Annual Report 2023. Jakarta: Ministry of National Development Planning.
- Chen, X., Zhang, L., & Li, H. (2023). Integrating digital governance and low-carbon transition in smart cities. *Sustainable Cities and Society*, 92, 104506.
- ESDM. (2023). Indonesia Energy Outlook 2023. *Jakarta: Ministry of Energy and Mineral Resources*.
- Forrester, J. W. (1961). *Industrial Dynamics*. MIT Press.
- Geels, F. W. (2021). Transformative innovation and system reconfiguration in energy transitions. *Research Policy*, 50(9), 104299.
- Gupta, A., & Pardo, T. (2021). Smart governance for climate-resilient cities: Data, policy, and participation. *Government Information Quarterly*, 38(4), 101619.
- IEA. (2022). Global EV Outlook 2022: Securing Supplies for an Electric Future. *Paris: International Energy Agency*.
- Levin, T., Geyer, R., & Hansen, S. (2022). Feedback loops and unintended consequences in urban mobility systems. *Environmental Modelling & Software*, 154, 105463.
- Nurhadi, N., & Suryani, D. (2021). Urban transport, social inequality, and sustainable city transformation in Jakarta. *Cities*, 119, 103380.
- OECD. (2020). *Smart Cities and Inclusive Growth: Building on the OECD Principles on Urban Policy*. Paris: OECD Publishing.
- Richardson, G. P. (2013). Conceptualization and validation of System Dynamics models. *System Dynamics Review*, 29(2), 102–123.
- Schipper, L., Ting, M., & Chen, Y. (2020). The rebound effect revisited: Transport policy and behavioral adaptation. *Energy Policy*, 144, 111671.

- Setiawan, R., Wibowo, A., & Kusnadi, D. (2023). Smart city transformation and emission mitigation strategies in Indonesia. *Journal of Urban Management*, 12(2), 87–101.
- Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill.
- Wang, Y., Park, J., & Choi, S. (2022). Electrification and digitalization of urban transport in Asia: Comparative policy analysis. *Transportation Research Part D: Transport and Environment*, 107, 103297.
- Yoon, S., Kim, J., & Lee, H. (2022). Smart mobility and carbon-neutral transition: Lessons from Seoul's innovation ecosystem. *Energy Reports*, 8, 10497–10509.
- Zhang, K., Wu, T., & Zhao, L. (2022). Pathways toward net-zero smart cities: Integration of energy and transport systems. *Renewable and Sustainable Energy Reviews*, 160, 112345.
- Zhao, X., & Li, D. (2021). Dynamic simulation of carbon neutrality in metropolitan transport systems. *Applied Energy*, 299, 117329.
- Zhu, J., & Chen, X. (2023). Policy integration for low-carbon and smart urban governance. *Energy Research & Social Science*, 98, 103002.
- Zhou, W., & Zhao, P. (2022). Understanding urban transition through systems thinking: Case evidence from Beijing. *Cities*, 121, 103491.

LITERATURE STUDY ON THE ROLE OF EDUCATION END PUBLIC PARTICIPATION IN MARINE PLASTIC POLLUTION REDUCTION

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *nida.farah@mhs.unj.ac.id

Abstract

Marine plastic pollution is one of the most urgent global environmental challenges of the 21st century, with serious ecological, economic, and social consequences. Its accumulation causes ecosystem degradation, threatens biodiversity, and introduces microplastics into the human food chain. Although various technical solutions have been developed, they are insufficient without behavioral change. Education and public participation are therefore essential to encourage sustainable consumption and waste management practices. This literature review systematically examines 18 international and regional studies published between 2015 and 2025 to analysis the role of environmental education and community engagement in addressing marine plastic pollution. The findings show that school-based education, community programs, and citizen science can increase awareness, knowledge, and collective actions to reduce plastic use. Program effectiveness depends on curriculum quality, facilitator capacity, inclusiveness, and long-term community participation. Integrating environmental education into formal systems and fostering active public involvement are strategic efforts for sustainable marine plastic pollution control.

Keywords: marine debris, plastic pollution, environmental education, public participation, sustainability.

Introduction

Plastic pollution in the marine environment has become one of the most critical ecological crises in the 21st century. Every year, millions of tons of plastic enter the oceans, threatening marine biodiversity, fisheries sustainability, and even human health through the food chain. While engineering solutions such as waste collection, recycling, and technological innovation play essential roles, they alone are not sufficient.

The root causes of plastic pollution are deeply related to human behavior, consumption patterns, and a lack of public awareness. Therefore, education and public participation are increasingly recognized as crucial elements to complement technical measures in addressing this issue. Education, particularly environmental education, has the potential to build long-term cultural shifts in society towards sustainable consumption and production patterns. Similarly, public participation, ranging from community engagement to citizen science projects, provides opportunities for individuals to take part in plastic pollution reduction efforts.

This paper aims to explore how education and public participation contribute to marine plastic pollution control, based on a systematic review of literature published between 2015 and 2025.

Method

This research employed a systematic literature review (SLR) approach to analyze the role of education and public participation in reducing marine plastic pollution. A total of 18 peer-reviewed publications published between 2015 and 2025 were examined. The literature search was conducted using databases such as Scopus, Web of Science, and Google Scholar with relevant keywords including “marine plastic pollution”, “environmental education,” “public participation,” and “citizen science.” The inclusion criteria consisted of studies explicitly addressing education or public participation in relation to marine plastic pollution control, empirical and review articles, and publications written in English or Indonesian. The analysis focused on identifying various educational strategies, public engagement mechanisms, and their effectiveness in reducing plastic waste in marine ecosystems. Through this method, the study aimed to provide a comprehensive understanding of how education and active community involvement contribute to sustainable solutions for marine plastic pollution.

Result and Discussion

Results are the main part of scientific articles because they provide the empirical basis on which arguments and conclusions are built. In this study, the results were obtained from a systematic literature review covering 18 scientific publications between 2015 and 2025, both at the international and regional level. The analysis of these publications shows three dominant thematic clusters, namely the role of environmental education, the contribution of public participation, and the integration of education with participation. These findings were not only recorded in descriptive form, but also supported by synthesis in the form of comparative tables that illustrate the different approaches and outcomes of each study. Presenting the results in this way is important because it enables readers to clearly distinguish the relative contributions of education and participation, while at the same time appreciating their interconnections in addressing the complex problem of marine plastic pollution.

Table 1. Summary of Key Findings from Literature Review

Focus Area	Key Findings
Environmental Education	School-based programs raise awareness; curriculum integration fosters sustainable behavior
Public Participation	Community clean-ups, citizen science projects generate data and build responsibility
Integration	Combining education and participation strengthens policy advocacy and long-term impact

The discussion is considered the most crucial part of the entire content of a scientific article because it not only explains the meaning of the results but also connects them to broader theoretical and practical contexts. The main purpose of the discussion in this paper is to answer the research question regarding how education and public participation contribute to the control of marine plastic pollution, to interpret the findings of the literature review, and to integrate those findings into the existing body of knowledge, so that eventually they can either support existing theories or contribute to the development of new conceptual frameworks.

From the reviewed literature, it becomes evident that environmental education plays a significant role in shaping knowledge, attitudes, and behaviors related to plastic consumption and waste management. Several studies emphasized that when environmental education is systematically integrated into the school curriculum, it generates long-term behavioral change among students who then act as agents of change within their families and communities. However, education in isolation has limitations. Without practical avenues for students and

citizens to apply their knowledge, awareness tends to remain abstract and does not translate into sustainable behavioral practices. This limitation confirms earlier findings by Jambeck et al. (2015) and UNEP (2021), who stressed that plastic pollution cannot be resolved solely through technological or knowledge-based solutions but requires behavioral transformation and structural social change.

The results of this study further demonstrate that public participation offers the necessary practical dimension that complements education. Initiatives such as coastal clean-up programs, waste segregation campaigns, and citizen science projects not only reduce the amount of waste entering the ocean but also provide tangible experiences that reinforce environmental values. Citizen science, in particular, has been shown to enhance scientific literacy while producing useful data for policymakers and researchers (García-Vazquez & García-Ael, 2021). Thus, public participation acts as both a means of environmental management and an informal educational process that reinforces awareness and responsibility at the individual and collective level.

An important finding of this review is the synergistic effect that occurs when education and public participation are integrated. Educational programs that are connected to participatory activities such as students being involved in community monitoring of marine litter, or school projects linked to municipal waste management programs—create stronger and more sustainable impacts compared to isolated interventions. This integration allows theoretical knowledge to be immediately connected with practical action, thereby increasing the probability of long-term behavioral change. It also contributes to building social capital, because collaborative activities between schools, communities, NGOs, and government institutions encourage trust, communication, and collective responsibility.

Interpreting these findings in the context of existing environmental behavior theories, it can be argued that integration between education and participation offers a refinement of the traditional knowledge-attitude-behavior (KAB) model. While the KAB model suggests that knowledge leads to changes in attitude and eventually in behavior, evidence from this literature review shows that active participation acts as a mediating factor that accelerates and stabilizes this transformation. In other words, participation bridges the gap between awareness and action. This suggests that future environmental education theories must incorporate participatory components as an integral dimension rather than as optional activities.

The significance of these findings lies not only in their academic contribution but also in their practical implications for policymakers and practitioners. Governments and NGOs should design interventions that link school-based education programs with community-based participation initiatives. For example, curricula that teach about marine plastic pollution should be complemented by opportunities for students to engage in real-world projects such as local waste audits, recycling initiatives, or beach clean-ups. Such integrated models not only enhance learning outcomes but also provide direct environmental benefits.

In conclusion, the results and discussion of this study strongly support the argument that marine plastic pollution is a socio-ecological challenge requiring integrated solutions. Education alone provides knowledge and awareness, while participation provides practice and ownership. The integration of both creates a holistic approach that can potentially transform societal behavior toward sustainable waste management and plastic pollution control.

Conclusion

Marine plastic pollution is not only a technological or policy issue but also a socio-cultural challenge that requires changes in human behavior. This study demonstrates that environmental education and public participation are essential components in reducing marine plastic pollution. The review reveals that education programs integrated into school curricula, combined with participatory approaches such as citizen science and community engagement, can create

significant positive impacts. However, long-term success depends on factors such as curriculum inclusiveness, facilitator competence, and the sustainability of public involvement. It is recommended that governments, NGOs, and educational institutions collaborate in strengthening environmental education, encouraging public participation, and ensuring policy support for sustainable waste management. Future research should focus on evaluating the effectiveness of integrated education-participation models across different cultural and socio-economic contexts.

Acknowledgment

The authors would like to thank the Graduate School of Environmental Management, State University of Jakarta, for the academic support and resources that enabled this research. Appreciation is also extended to colleagues and reviewers whose insights have contributed to the improvement of this paper.

References

- Andrady, A. L. (2017). The plastic in microplastics: A review. *Marine Pollution Bulletin*, 119(1), 12–22.
- Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B*, 364(1526), 1985–1998.
- Borrelle, S. B., et al. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science*, 369(6510), 1515–1518.
- Chen, Y., Li, P., & Zhang, H. (2023). Evaluating the impact of environmental education on plastic waste reduction behavior among coastal communities. *Sustainability*, 15(12), 9763.
- Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., & Reisser, J. (2024). Global plastic waste pathways and governance challenges: Integrating education and public participation for ocean sustainability. *Marine Pollution Bulletin*, 199, 115014.
- García-Vazquez, E., & García-Ael, C. (2021). Citizen science and marine litter: From awareness to action. *Marine Policy*, 124, 104332.
- Jambeck, J. R., et al. (2015). Plastic waste inputs from land into the ocean. *Science*, 347(6223), 768–771.
- Kwon, O. Y., & Lee, S. H. (2023). Environmental education and plastic waste reduction: A systematic review. *Sustainability*, 15(4), 2549.
- Li, W. C., Tse, H. F., & Fok, L. (2016). Plastic waste in the marine environment: A review of sources, occurrence and effects. *Science of the Total Environment*, 566–567, 333–349.
- Mukherjee, A., & Rahim, S. A. (2025). Integrative frameworks for community participation in plastic pollution governance. *Ocean & Coastal Management*, 252, 107345.
- Nielsen, T. D., Hasselbalch, J., Holmberg, K., & Stripple, J. (2019). Politics and the plastic crisis: A review throughout the plastic life cycle. *Wiley Interdisciplinary Reviews: Energy and Environment*, 9(1), e360.
- Rahman, F., & Sari, D. M. (2025). Strengthening community-based environmental education to reduce coastal plastic waste in Southeast Asia. *Journal of Environmental Management and Sustainability*, 12(2), 98–112.
- Rochman, C. M., et al. (2016). Policy: Classify plastic waste as hazardous. *Nature*, 494(7436), 169–171.
- Ryan, P. G. (2020). A brief history of marine litter research. In *Marine Anthropogenic Litter* (pp. 1–25). Springer.
- Schultz, P. W. (2011). Conservation means behavior. *Conservation Biology*, 25(6), 1080–1083.
- Tanaka, K., & Santos, I. R. (2024). Linking citizen science and environmental literacy for marine

plastic monitoring. *Frontiers in Marine Science*, 11, 145677.

UNEP. (2021). *From Pollution to Solution: A global assessment of marine litter and plastic pollution*. United Nations Environment Programme.

UNESCO. (2022). *Education for Sustainable Development: A roadmap*. Paris: UNESCO.

Velis, C. A., & Cook, E. (2021). Mismanagement of plastic waste through open burning: A global health disaster. *Environment International*, 147, 106367.

Xanthos, D., & Walker, T. R. (2017). International policies to reduce plastic marine pollution from single-use plastics. *Marine Policy*, 96, 184–190.

ECONOMIC

**OPTIMIZING MANGROVE CARBON STOCKS TO ACHIEVE
INDONESIA'S FOLU NET SINK 2030 TARGET:
ENVIRONMENTAL ENGINEERING SCIENCE PERSPECTIVE**

Faisal M Jasin

*Environmental Engineering Study Program, Institut Kesehatan dan Teknologi PKP Jakarta,
Indonesia*

E-mail: *faisal.mjasin@iktj.ac.id

Abstract

This Research seeks to examine and boost the amount of carbon stored in mangrove forests, as a key action to help Indonesia reach its 2030 Forestry and Other Land Use Net Sink target, using a mix of environmental engineering knowledge combined with rules and tracking methods. The gains from this Research include giving ideas and tangible actions for managing coastal areas based on science, while backing policies to deal with climate change by fixing mangrove areas in ways that work well and last. The ideas shown in this article cover blue carbon areas, which highlight how important mangroves are for soaking up carbon for a long time, along with environmental engineering knowledge that joins together water engineering, soil management, and bioengineering to make the area better at doing its job. It was done using a mix of methods, including looking at areas using satellite pictures (GIS), figuring out carbon amounts using the IPCC Tier 2 method, doing surveys in the field, talking with important people, and judging how well the environmental engineering steps work. This Research shows that the amount of carbon stored in mangrove areas at the study site is about 350 to 950 tons C/ha, and there is a big chance of fixing damaged areas. Environmental engineering actions like fixing water flow, putting in things to catch soil, and using bioengineering can help gather more carbon and make repair work successful. Making mangrove restoration as good as it can be might add up to about 5 to 7 Mt CO_{2e} each year, which makes it a helpful answer to reaching the aims of the 2030 Forestry and Other Land Use Net Sink goal.

Keywords: Mangrove; Carbon Stock; Blue Carbon Ecosystem; Environmental Engineering; FOLU Net Sink 2030

Introduction

Mangrove ecosystems are known worldwide as very good at absorbing carbon from the air naturally, and they can keep carbon in their living parts and muddy ground without air for many years (Rijal et al., 2024). The Carbon Absorption idea says that areas that grow a lot and break down slowly like mangrove forests are significant for fighting climate change by holding carbon for a long time. Indonesia has the biggest mangrove area in the world, with over 3.3 million hectares, about 23% of all the mangrove forests globally (Arifanti et al., 2024). These areas are significant for the environment and the economy, especially in helping to reduce climate change (Lubis et al., 2025). Mangroves are called blue carbon ecosystems, meaning coastal areas that can take in and store much carbon, both in the plants above the ground and in the stable, airless mud for hundreds or thousands of years (Reid & Wood, 2026).

Despite being ecologically rich, mangrove forests in Indonesia are getting seriously damaged (Indra et al., 2025). The Environment and Forestry Ministry (KLHK) says that almost 600,000 hectares of mangroves are in bad shape because of fish farms, coastal building, and unsustainable land use (Iskandar et al., 2023). This damage not only reduces the variety of plants and animals and protection for the coast but also puts the carbon-absorbing ability of these areas at risk (Arifanti et al., 2024).

To address this, the Indonesian government started the FOLU Net Sink 2030 plan (Dharmawan & Pratiwi, 2023), which aims to have no net emissions from forests and land use by 2030 (Purushotham & Thompson, 2026). Restoring mangrove forests is a key part of this plan, because they absorb carbon and help protect against climate change (Kisinger & Matsui, 2021). However, reaching this goal requires more than just fixing the environment—using science and special techniques to make carbon storage as good as possible (Indra et al., 2025; Parker et al., 2018).

This study uses the Environmental Engineering Science View, including ideas from how ecosystems work (Reid & Wood, 2026), water flow, and how land shapes itself near water, to create and test mangrove restoration plans (Yu et al., 2013). Using tools like remote sensing, carbon measuring, and water study methods, we want to measure and improve how well mangroves in Indonesia can absorb carbon (Indra et al., 2025).

In reality, Indonesia's actual state of mangroves is significantly declining (Iskandar et al., 2023). The Environment and Forestry Ministry (KLHK) reports that about 637 thousand hectares of mangroves are damaged, mostly from changing the land into fish ponds, homes, and coastal structures (Arifanti et al., 2024). This decline endangers plant and animal diversity and coastal safety and releases much carbon into the air, adding to the country's greenhouse gas emissions (Arifanti et al., 2024).

On the other hand, the ideal situation means Indonesia needs to reach its big goal for the forestry sector by 2030 (Dharmawan & Pratiwi, 2023), which is to make forests and land use remove 140 million tons of CO₂e each year. In Indonesia's plan for this forestry goal by 2030, fixing and protecting mangrove forests is a primary strategy: restore 600 thousand hectares of mangroves by 2024 (Setyadi et al., 2021). However, reaching this goal depends on how much land is restored and how well the methods and scientific methods work to make the most of carbon storage (A. Twomey & Lovelock, 2024).

In this situation, environmental engineering science gives a step-by-step and technology-based way to improve how healthy mangroves absorb carbon (Ratliff et al., 2017). This includes changing water flow to bring back tidal flows, managing soil to help build carbon, and using sensors and satellite images to check carbon storage in real-time (A. J. Twomey & Lovelock, 2025). Also, including local people in watching over and taking care of mangroves is very important for long-term success by combining it with social and environmental ways (Karniati et al., 2021).

So, there is a gap between what is happening and the ideal goal, and we need to close this gap with a mix of different ways of thinking (Hindrasti & Putri, 2021). This study wants to look closely at how environmental engineering can help make the most of mangrove carbon storage in Indonesia to help reach the forestry goal by 2030 (Ati et al., 2023). Hopefully, this study can give helpful ideas and real-world ways to create policies and technologies for managing coastal areas sustainably and scientifically (Dulyakasem et al., 2026).

Method

This Research uses a mixed-methods approach (Creswell & Creswell, 2018), combining numerical and descriptive methods to understand how to use mangrove carbon storage best to help reach the FOLU Net Sink 2030 goals. This method includes several steps, as follows:

Research Design

This study explores and describes information using various fields, such as environmental science, environmental engineering, and public policy. The main goal is to find, study, and create environmental engineering plans to use mangrove carbon storage to its best.

Location and Research Subjects

The study was done in some mangrove areas of Muara Gembong, Bekasi Regency. The things studied include: The size and state of the mangrove ecosystem, the amount of carbon in plants and soil, and Environmental engineering actions that have been used. Data was gathered as primary data through field surveys to measure mangrove plant life (diameter, tree height, type of plant), and in-depth talks with people involved (local government, coastal communities, NGOs). Secondary Data comprised satellite images (Landsat, Sentinel) to study how mangrove cover changes over areas, policy papers, and technical reports from the Ministry of Environment and Forestry, the BRGM, and global groups.

Data Analysis

Carbon Storage Estimates: The IPCC Tier 2 method determines the amount of carbon stored above and below the ground. Spatial Analysis: Using GIS software to map how mangrove cover changes and chances for restoration. Environmental Engineering Analysis: Checking how well engineering actions work, like restoring water flow, managing soil, and using plants for engineering. Qualitative Analysis: Using a thematic analysis approach to find problems and opportunities in putting mangrove restoration policies into place.

Validation and Triangulation.

Validation was done by comparing data from different sources (field, satellite images, and talks) to ensure that the research results were correct and consistent.

Result and Discussion

Estimates of Mangrove Carbon Stock

Spatial analysis and field measurements show a variation in the average total carbon (biomass over and under ground, as well as soil carbon) at study sites. Depending on the degree of harm and the vegetation present, between 350 and 950 tons C/ha. Areas with natural mangroves still intact display far more carbon storage capacity than regions turned into ponds or open ground.

Identifying Restoring Priority Zones

Using spatial modeling based on Landsat 8 and Sentinel-2 satellite images, it was discovered that approximately 27% of the entire mangrove area in the research location was under moderate to severe damage conditions. Because they have good hydrologic connection and access that enables the application of restoration methods, these areas have great potential for restoration.

Appraisal of Interventions in Environmental Technology

At the study site, several environmental technical methods were tested, and the results are: With the application of channel pasang surut and clearing of natural channels, Restorasi Hidrologi raises the frequency of pasang surut by as much as 35%, hence supporting root growth and sediment accumulation. Structure of sediment traps: Installing brushwood constructions and bamboo fencing speeds sediment accumulation to 2.5 cm annually, accelerating substrate formation for mangrove regeneration. Bioengineering of local penanaman species, such as *Rhizophora mucronata* and *Avicennia marina*, using the mycorrhizal inoculation method showed a seedling survival rate of 85% in the first 12 months.

Relationship with Target FOLU Net Sink 2030

Optimizing mangrove restoration in the study area with conservative projections might contribute up to 5 to 7 Mt CO₂e per year toward the target FOLU Net Sink 2030. Still, the continuity of technical interventions, cross-sectoral policy support, and engaged local community participation will determine this accomplishment.

Opportunities and Challenges

The main obstacles to carrying out restoration depending on technology are institutionalization, limited funding, and a lack of precise spatial data. Opportunities arise to improve the sustainability of mangrove restoration projects by integrating sensor and drone monitoring technology and carbon financing schemes.

Conclusion

Indonesia's mangroves have great potential as carbon sinks to support the FOLU Net Sink 2030, but ecosystem degradation reduces this capacity. Research shows that environmental engineering interventions such as hydrological restoration, sediment management, and bioengineering significantly increase carbon stocks and rehabilitation success. With the support of integrated monitoring and policy technologies, mangrove optimization can contribute up to 5– 7 Mt CO₂e/year, making it a strategic solution for climate change mitigation and sustainable coastal management. Conceptually, this Research strengthens the paradigm of environmental engineering science in managing coastal ecosystems, combining ecological, technological, and social aspects. In practical terms, these findings can serve as the basis for developing scalable engineering-based restoration models and supporting national policies and international carbon finance mechanisms.

Acknowledgment

BIMA funds this Research.kemdiktisaintek (Contract Number 124/C3/DT.05.00/PL/2025 and 0911/LL3/AL.04/2025). Thank you to the Ministry of Environment/Environmental Control Agency of the Republic of Indonesia as a research partner and the Ministry of Forestry of the Republic of Indonesia for helping to provide data in the form of mangrove maps of Muara Gembong. We would also like to thank the Rector of the Jakarta PKP Institute of Health and Technology for his continuous guidance, motivation, and institutional support during the research process. All of this support is an important foundation for the success of this research, which is making a real contribution to the development of science and environmental sustainability in Indonesia and the world.

References

- Arifanti, V. B., Candra, R. A., Putra, C. A. S., Asyhari, A., Gangga, A., Ritonga, R. P., Ilman, M., Anggoro, A. W., & Novita, N. (2024). Greenhouse gas fluxes of different land uses in mangrove ecosystem of East Kalimantan, Indonesia. *Carbon Balance and Management*, 19(1). <https://doi.org/10.1186/s13021-024-00263-3>
- Ati, R. N. A., Kepel, T. L., Kusumaningtyas, M. A., Sudirman, N., Salim, H. L., Solihuddin, T., Heriati, A., & Mustikasari, E. (2023). Mangrove Bio-Ecology for Rehabilitation Purposes in Pandeglang. *IOP Conference Series: Earth and Environmental Science*, 1148(1). <https://doi.org/10.1088/1755-1315/1148/1/012045>
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*.
- Dharmawan, I. W. S., & Pratiwi. (2023). Implementation of forest-land rehabilitation to support the enhancement of carbon stock on Indonesia's FOLU net sink 2030 strategy.

- IOP Conference Series: Earth and Environmental Science*, 1180(1).
<https://doi.org/10.1088/1755-1315/1180/1/012010>
- Dulyakasem, R., Brooks, C., Lehnert, S. L., & Newton, P. (2026). Community-based natural resource management in coastal communities: The contribution of mangroves to household livelihoods in southern Thailand. *Environmental Development*, 57.
<https://doi.org/10.1016/j.envdev.2025.101340>
- Hindrasti, N. E. K., & Putri, A. N. (2021). The identification of preservice biology teacher's misconceptions on the concept of mangrove ecology using the certainty of response index (CRI). *Journal of Physics: Conference Series*, 1940(1).
<https://doi.org/10.1088/1742-6596/1940/1/012124>
- Indra, T. M. S., Karim, A., & Dahlan, D. (2025). Individual Density and Carbon Potential in the Nipah Ecotourism Development Area, West Aceh Regency, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1477(1).
<https://doi.org/10.1088/1755-1315/1477/1/012044>
- Iskandar, M., Siregar, I. Z., & Krisnawati, H. (2023). Potential of carbon sequestration enhancement through intensive silvicultural techniques using *Shorea leprosula* plantation in Central Kalimantan, Indonesia. *Biodiversitas*, 24(8), 4699–4513.
<https://doi.org/10.13057/biodiv/d240852>
- Karniati, R., Sulistiyono, N., Amelia, R., Slamet, B., Bimantara, Y., & Basyuni, M. (2021). Mangrove ecosystem in north sumatran (Indonesia) forests serves as a suitable habitat for mud crabs (*scylla serrata* and *s. olivacea*). *Biodiversitas*, 22(3), 1489–1496.
<https://doi.org/10.13057/biodiv/d220353>
- Kisinger, C., & Matsui, K. (2021). Responding to climate-induced displacement in bangladesh: A governance perspective. *Sustainability (Switzerland)*, 13(14), 1–12.
<https://doi.org/10.3390/su13147788>
- Lubis, O. A., Thoha, A. S., Slamet, B., Ulfa, M., Mardiyadi, Z., & Randani, D. Z. (2025). *Estimation of mangrove above-ground carbon stock using unmanned aerial vehicle in the community forest area in Deli Serdang, North Sumatra, Indonesia* (Vol. 18).
<http://www.bioflux.com.ro/aacl>
- Parker, L., Prabawa-Sear, K., & Kustiningsih, W. (2018). How young people in Indonesia see themselves as environmentalists: Identity, behaviour, perceptions and responsibility. *Indonesia and the Malay World*, 46(136), 263–282.
<https://doi.org/10.1080/13639811.2018.1496630>
- Purushotham, M. K., & Thompson, B. S. (2026). Incorporating blue carbon into climate change mitigation policies: Multi-level governance challenges for carbon credits and NDCs. *Ecological Economics*, 240, 108800.
<https://doi.org/10.1016/j.ecolecon.2025.108800>
- Ratliff, K. A., Howell, J. L., & Redford, L. (2017). Attitudes toward the prototypical environmentalist predict environmentally friendly behavior. *Journal of Environmental Psychology*, 51, 132–140. <https://doi.org/10.1016/j.jenvp.2017.03.009>
- Reid, J., & Wood, D. (2026). Supporting sustainable mangrove management in Rio de Janeiro, Brazil: An application of the Environment-Vulnerability-Decision-Technology systems engineering framework. *Acta Astronautica*, 238, 112–134.
<https://doi.org/10.1016/j.actaastro.2025.08.050>
- Rijal, S. S., Furqon, M. T., Kadhafi, M., Supriatin, F. E., & Aprilianto, R. Y. (2024). Mangroves in Alas Purwo National Park, Indonesia: Diversity and Its Potential Carbon

Services. *HAYATI Journal of Biosciences*, 31(3), 589–595. <https://doi.org/10.4308/hjb.31.3.589-595>

Setyadi, G., Pribadi, R., Wijayanti, D. P., & Sugianto, D. N. (2021). Mangrove diversity and community structure of mimika District, Papua, Indonesia. *Biodiversitas*, 22(8), 3562–3570. <https://doi.org/10.13057/BIODIV/D220857>

Twomey, A. J., & Lovelock, C. E. (2025). Variation in Mangrove Geometric Traits Among Genera and Climate Zones. *Estuaries and Coasts*, 48(2). <https://doi.org/10.1007/s12237-025-01487-3>

Twomey, A., & Lovelock, C. (2024). Global spatial dataset of mangrove genus distribution in seaward and riverine margins. *Scientific Data*, 11(1), 306. <https://doi.org/10.1038/s41597-024-03134-1>

Yu, D., Shi, P., Liu, Y., & Xun, B. (2013). Detecting land use-water quality relationships from the viewpoint of ecological restoration in an urban area. *Ecological Engineering*, 53, 205–216. <https://doi.org/10.1016/j.ecoleng.2012.12.045>

INTEGRATION OF ENVIRONMENTAL MANAGEMENT AND GREEN ECONOMY: A CASE STUDY OF KAMPUNG LABIRIN BOGOR

Arradina Zessa Devy^{1*}, Yusup Ajang Setiadi², and Arief Aditya Hutama³

¹*Postgraduate Faculty, State University of Jakarta, Jakarta, Indonesia*

²*Faculty of Economics and Business, State University of Jakarta, Jakarta, Indonesia*

³*PRVKP UI, University of Indonesia, Jakarta, Indonesia*

E-mail: [*arradinazessadevy@mhs.unj.ac.id](mailto:arradinazessadevy@mhs.unj.ac.id)

Abstract

Urbanization in developing countries like Indonesia intensifies housing and settlement challenges, exacerbating slums, environmental degradation, and socioeconomic inequality. This research examines the integration of environmental management and green economy principles to build urban community resilience, using Kampung Labirin in Bogor as a case study. A systematic literature review with narrative synthesis, following the PRISMA protocol, was employed to analyze multi-stakeholder collaboration in transforming a former slum into a sustainable tourist village. Findings reveal that success was driven by collaborative governance, local economic empowerment through MSMEs, sustainable tourism, and creative waste management. The study concludes that this integrated model offers a replicable framework for sustainable urban development, though long-term sustainability requires ongoing effort. The Kampung Labirin case highlights the critical role of community participation and green economy strategies in enhancing urban resilience.

Keywords: urban resilience, green economy, sustainable tourism, community empowerment, systematic literature review, Kampung Labirin

Introduction

Housing and settlement issues are becoming increasingly urgent, especially in developing countries experiencing rapid urbanisation. Rapid population growth, particularly in urban areas, places enormous pressure on infrastructure and land availability. The significant impact of irreversible changes to urban socio-ecological, cultural and economic systems, particularly in relation to human settlement considerations, is serious and counterproductive to the process of sustainable development (Damte et al, 2022). This tendency is especially noticeable in Indonesia, where the population has been living in cities for the past few decades at a rapid rate. Numerous reasons, including industrialization, job opportunities, population increase, and modernization, have fueled the urbanization process (Humbal et al., 2023). Projections indicate that more than 60% of the world's population will live in urban areas by 2050 and expected to increase by 2–3 billion by 2050.

Urbanization is a phenomenon that affects rural areas as well as urban areas and is viewed as a sign of both social and economic progress in urban areas (Wesnawa et al., 2023). Rapid urban center expansion is a defining feature of this demographic transformation, bringing with it benefits and challenges that need careful consideration (Telaumbanua, 2024). The exceptional pace and magnitude of demographic changes in Indonesia's urban landscape make it imperative to fully

comprehend the processes of urbanization. Given that the population is expanding quickly and that a larger proportion of people live in cities, it is urgent to address the opportunities and problems brought about by urbanization. If these problems are not resolved quickly, socioeconomic inequality may increase, metropolitan infrastructure may become more stressed, environmental sustainability may be jeopardized, and social cohesiveness may be weakened (Anggraeni, 2022; Dahlan et al., 2021; Indah, 2022; Silver, 2022; Susiati, 2022). Uncontrolled urbanisation has led to the emergence of slums in large cities (Huang et al., 2019), meanwhile unchecked urbanization has, meanwhile, also had unfavorable effects, such as slum expansion, air pollution, and environmental deterioration (Kopadze & Jikurashvili, 2023).

Kampung Labirin was chosen as a unique case study due to its transformation from a slum area on the banks of the Ciliwung River into a tourist destination supported by CSR and government policies. The research question is how the integration of environmental management and the green economy is implemented in Kampung Labirin and how this integration contributes to building urban community resilience.

Method

This research was conducted from August to September 2025 in Kampung Labirin, Babakan Pasar village, Bogor Tengah sub-district, Bogor City, located on the banks of the Ciliwung River and directly behind the Baranangsiang Terminal. This location was deliberately chosen (purposive) because Kampung Labirin is a concrete example of an urban community undergoing transformation through the integration of environmental management and the green economy, as documented in previous studies (Nugraha et al., 2023; Putra et al., 2023). This study uses a systematic literature review with a narrative synthesis approach to analyze the integration of environmental management and green economy in building urban community resilience. A narrative synthesis approach was adopted given the predominantly descriptive and quantitative nature of the evidence while maintaining the flexibility to accommodate qualitative evidence (Osuh et al., 2024). The literature review was conducted systematically following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. This literature review method is designed to provide a comprehensive and systematic analysis to understand the dynamics of environmental management and green economy integration in Kampung Labirin Bogor.

Result and Discussion

Kampung Labirin has undergone a significant transformation from an urban slum to a sustainable tourist destination. Before the intervention, the area faced classic problems of dense settlements such as school dropouts, unemployment, poor infrastructure, and low environmental awareness (Nugraha et al., 2023). Through a collaborative programme involving the local government, PT Astra International, and the Terminal Hujan Foundation, physical infrastructure improvements and community capacity building took place.

Kampung Labirin, based on the Decree of the Mayor of Bogor, West Java Province, Number 556/Kep.97-Disparbud/2022 dated 18 March 2022, was designated as one of the tourist villages in the city of Bogor (Permata, 2022). However, in recent years, various tourist villages in Indonesia have faced a number of problems, including a tendency to focus more on exploring or even exploiting their natural resources in order to attract more tourists (Manaf et al., 2018; Sesotyaningtyas & Manaf, 2015). This behaviour has an impact on the attractiveness of the tourist village itself, which is increasingly reduced (Fletcher et al., 2018). These various conditions are inseparable from their relationship with the physical and natural environment in the tourist village concerned (Pariwisata & Desa, 2015). In order to address environmental issues in tourist villages, one of the concepts introduced is the Green Tourist Village concept.

A green tourism village can be defined as the development of a tourism village based on the empowerment of local communities, with reference to the principles of natural environment conservation, and supported by the local economy and socio-culture. The use of the word ‘green’ implies that managers need to combine tourism activities with production and nature conservation activities, or in other words, implement environmentally friendly tourism practices (Pariwisata & Desa, 2015). This model was introduced by the UN Environmental Programme (2015), which states that the involvement of the local community is an absolute requirement. However, obstacles often arise from the capacity and understanding of the community about green tourism villages themselves. Therefore, a social intervention programme is needed that is oriented towards increasing the community's understanding and capacity in pro-environmental behaviour.

The development of Kampung Labirin integrates green economy principles through the development of MSMEs based on local products (jengkol crackers and jengkol chips), utilisation of the Ciliwung River for sustainable water tourism, development of local arts and culture (angklung, marawis, traditional dance) as tourist attractions and implementation of a waste management system using maggot cultivation (Aziz, 2023; Putra et al., 2023).

Research findings indicate that the integration of environmental management and the green economy in Kampung Labirin is achieved through a multi-stakeholder collaborative approach. As stated by Telaumbanua et al. (2024), investment in urban infrastructure and improved access to education are key factors in sustainable urban development. In Kampung Labirin, this integration is manifested in Table 1. Based on the SWOC analysis conducted by Nugraha et al. (2023), Kampung Labirin has strengths in its unique concept and strategic location, but faces challenges in infrastructure and promotion. Kampung Labirin's success in integrating environmental management and the green economy offers a sustainability model that can be replicated in other urban communities, particularly in terms of multi-stakeholder collaboration between the government, private sector, and community; local-based empowerment by optimising local potential; a sustainable approach that combines environmental and economic aspects; and creative adaptation in facing challenges such as the pandemic.

Tabel 1. Integration of Environmental Management and Green Economy in Kampung Labirin

ENVIRONMENTAL ASPECTS	GREEN ECONOMY ASPECTS	INTEGRATION RESULTS
Waste management with maggots	Sales of organic fertiliser	Waste reduction + additional income
Greening the village with ornamental plants	Photo spots for tourists	Beautiful surroundings + tourist attractions
Restoration of the Ciliwung River	Water tourism (boats, kayaks)	Water conservation + tourism businesses
Murals and wall art	Instagrammable photo destinations	Environmental aesthetics + tourism promotion

Conclusion

The integration of environmental management and green economy in Kampung Labirin, Bogor, has shown positive results in building urban community resilience, although further development is still needed to ensure long-term sustainability. In practical terms, the Kampung Labirin model offers an alternative for sustainable urban community development, particularly in addressing the classic problems of dense urban settlements. As stated in a study on informal settlements (Aboulnaga et al., 2021), a participatory approach and community empowerment are key to the successful upgrading of slum areas.

Acknowledgment

The author would like to express his deepest gratitude and appreciation to Anggun Pesona and Irma Sela, founders of Yayasan Terminal Hujan, as strategic partners who have provided access and support in the form of important data and information regarding Kampung Labirin.

References

- Aboulmaga, M., Badran, M.F. and Barakat, M. (2021). Global Informal Settlements and Urban Slums in Cities and the Coverage. Resilience of Informal Areas in Megacities – Magnitude, Challenges and Politics (pp.1-51).
- Anggraeni, F. A. (2022). Analisis Faktor Yang Mempengaruhi Peningkatan Urbanisasi Di Kota Jakarta Dan Surabaya Pada Tahun 2020-2021. *Jurnal Ekonomi Bisnis Dan Akuntansi*, 2(2), 41–53.
- Aziz, F.N. 2023. Pemberdayaan Pelaku UMKM melalui Yayasan Astra Honda Motor di Kampung Labirin, Kebon Jukut, Kota Bogor. UIN Syarif Hidayatullah Jakarta.
- Batubara, B., Kooy, M., Leynseele, Y. Van, Zwarteveen, M., & Ujjianto, A. (2023). Urbanization in (post-) New Order Indonesia: connecting unevenness in the city with that in the countryside. *The Journal of Peasant Studies*, 50(3), 1207–1226.
- Bentley, R., & Baker, E. (2022). Placing a housing lens on neighbourhood disadvantage, socioeconomic position and mortality. *The Lancet Public Health*, 7(5), e396–e397.
- Bhatnagar, S., Lovelace, J., Prushnok, R., Kanter, J., Eichner, J., LaVallee, D., & Schuster, J. (2023). A Novel Framework to Address the Complexities of Housing Insecurity and Its Associated Health Outcomes and Inequities: “Give, Partner, Invest.” *International Journal of Environmental Research and Public Health*, 20(14), 6349.
- Chevo, T. (2022). Kinship Relations and Urban Poverty. A Case Study of Budiriro in Harare, Zimbabwe. *African Perspectives on Poverty, Indigenous Knowledge Systems, and Innovation*. 97–10
- Dahlan, M. Z., Faisal, B., Chaeriyah, S., Hutriani, I. W., & Amelia, M. (2021). Review of Urban Greening Policy in Indonesia: A Case Study in Jakarta Province. *International Journal on Livable Space*, 6(1), 21–28.
- Damte E., Manteaw, B.O., and Wrigley-Asante, C. (2022). Urbanization, Climate Change, and Health Vulnerabilities in Slum Communities in Ghana. *The Journal of Climate Change and Health* 10(2023)100189.
- Hosgorur, T., Kizir, M., Sezer, S. Korkut, P., Kahya, O., Karaca Evren, M. Yildirim, K. Yesil, E., & Hosgorur, V. (2023). Reflections of urban poverty on education from the perspectives of school administrators. *Journal of Qualitative Research in Education*, 33, 46-70. doi: 10.14689/enad.33.1661
- Huang K., Li X., Liu X. and Seto K.C. (2019). Projecting Global Urban Land Expansion and Heat Island Intensification Through 2050. *Environmental Research Letters*, Vol 14 114037. DOI 10.1088/1748-9326/ab4b71
- Humbal, A., Chaudhary, N., & Pathak, B. (2023). Urbanization Trends, Climate Change, and Environmental Sustainability. In *Climate Change and Urban Environment Sustainability* (pp. 151–166). Springer.
- Indah, S. (2022). Dinamika Sosial Dan Budaya Masyarakat Urban. *Jurnal Kreatifitas Kebudayaan*. <https://doi.org/10.31219/osf.io/xbm3f>
- Kopadze, T., & Jikurashvili, M. (2023). Urbanization and its impact on population health. *Junior Researchers*, 1(1), 52–57.
- Masagung A.A. and Prasetyo. (2025). Perumahan dan Pemukiman Berkelanjutan : Solusi Inovatif untuk Tantangan Perkotaan Masa Kini. *Jurnal Cakrawala Ilmiah* Vol. 4, No 5.

- Nugraha R.N., Putra E.S., Salsabila R.A. and Wittsdy, J.H. (2023). Kebijakan Manajemen Saat Pandemi dan Pasca Pandemi, Desa Wisata Kampung Labirin Bogor Tengah. *Jurnal Ilmiah Wahan Pendidikan*, Desember 2023, 9(24), 625-636.
- Pariwisata, K., & Desa, K. (2015). *Buku Panduan Pengembangan Desa Wisata Hijau*.
- Permata, A.B. (2022). *Perencanaan Program Wisata di Tujuh Kampung Wisata di Kota Bogor, Provinsi Jawa Barat*. Bogor Agricultural University.
- Putra, J.S., Febrianto, W., Abigail, M.K., and Mahathir A. (2023). Internalisasi Perilaku Peduli Lingkungan pada Warga Desa Wisata Kampung Labirin Bogor. *I-Com : Indonesian Community Journal* Vol. 3 No.3 September 2023, Hal. 1139-1151
- Silver, C. (2022). History of Urban Planning in Indonesia, 1900–2020. In *Routledge Handbook of Urban Indonesia* (pp. 15–26). Routledge.
- Sesotyaningtyas, M., & Manaf, A. (2015). Analysis of Sustainable Tourism Village Development at Kutoharjo Village, Kendal Regency of Central Java. *Procedia - Social and Behavioral Sciences*, 184(August 2014), 273–280. <https://doi.org/10.1016/j.sbspro.2015.05.091>
- Susiati, A. (2022). Analysis of Migration Phenomenon and Urban Bias in Indonesia. *Formosa Journal of Sustainable Research*, 1(7), 1029–1040.
- United Nations–Human Settlements Programme [UN-Habitat]. (2015). *World atlas of slum evolution* working document produced for the United Nations Human Settlements Programme.
- Wesnawa, I. G. A., Sarmita, I. M., & Christiawan, P. I. (2023). Migrant Livelihood Challenges in Peri-Urban Area. *Proceedings of the 4th International Conference on Law, Social Sciences, and Education, ICLSSE 2022*, 28 October 2022, Singaraja, Bali, Indonesia.

INTEGRATING FOESG DIMENSIONS FOR SUSTAINABLE STRATEGIC PERFORMANCE IN THE SUGAR INDUSTRY

Luthfi Jusniar Dwiputri*, Eliana Sari, and Dian Alfia Purwandari

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *luthfi.jusniar@mhs.unj.ac.id

Abstract

This study examines the integration of Financial, Operational, Environmental, Social, and Governance (FOESG) dimensions to evaluate strategic sustainability performance in the sugar industry. Using a Systematic Literature Review (SLR) based on PRISMA 2020 guidelines, 52 peer-reviewed articles published between 2020 and 2025 were analyzed from Scopus, Web of Science, ScienceDirect, and Emerald Insight. The synthesis identifies fragmented research trends dominated by operational and environmental dimensions, with limited focus on governance and financial integration. The study develops a FOESG Strategic Performance Framework that positions governance as the central driver, aligning financial and operational enablers with social and environmental outcomes. Results indicate that systemic interdependence among FOESG dimensions enhances accountability, transparency, and long-term competitiveness. The framework provides both theoretical and managerial implications for achieving governance-driven sustainability transformation within resource-intensive industries.

Keywords: FOESG framework, sustainability performance, sugar industry, PRISMA 2020, strategic evaluation

Introduction

Globally, corporate sustainability practices are often framed within the Environmental, Social, and Governance (ESG) paradigm, which has become the dominant model for assessing non-financial performance and long-term value creation (Lozano, 2018). However, emerging research has revealed that ESG alone may not sufficiently capture the multidimensional realities of resource-intensive sectors such as sugar, where financial stability and operational capability are foundational to sustainable outcomes (Kumar & Singh, 2023). This gap underscores the need to develop a more comprehensive framework that incorporates financial and operational elements within sustainability performance measurement (Bătae et al., 2021; Rezaee & Tuo, 2019).

The theoretical basis for this research draws on three foundational perspectives. The Resource-Based View (RBV) posits that organizational performance and competitiveness stem from the possession and utilization of valuable, rare, and inimitable resources (Barney, 1991). Within this lens, financial capital and operational capabilities are viewed as key internal assets that drive innovation and sustainability in the sugar sector. The Stakeholder Theory (Freeman, 1984) provides a socio-governance perspective by emphasizing that long-term success depends on balancing the diverse interests of internal and external stakeholders. Meanwhile, the Triple Bottom Line (TBL) framework (Elkington, 1998) broadens the evaluation of corporate performance beyond financial metrics to include social and environmental outcomes. Together,

these theories provide a strong conceptual foundation for constructing the FOESG model, enabling an integrated view of sustainability performance.

Building upon these theoretical foundations, this study formulates the following problem statement: *How can the integration of financial, operational, environmental, social, and governance dimensions strengthen strategic sustainability performance in the sugar industry?* To address this, the research aims to (1) identify FOESG research trends and indicators from 2020–2025; (2) analyze the interrelations among the five dimensions; and (3) develop a conceptual framework for evaluating strategic sustainability performance.

Method

This study employs a Systematic Literature Review (SLR) to identify, analyze, and synthesize scholarly research related to the application of the FOESG (Financial, Operational, Environmental, Social, and Governance) framework in evaluating strategic performance within the sugar industry. The SLR method was chosen due to its ability to provide a rigorous, transparent, and reproducible synthesis of existing knowledge (Tranfield, Denyer, & Smart, 2003). To ensure methodological robustness, the research adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Moher et al., 2020). This approach allows for structured filtering, critical appraisal, and synthesis of peer-reviewed literature to generate both theoretical and practical insights into the integration of FOESG principles. Data were retrieved from four major academic databases—Scopus, Web of Science, ScienceDirect, and Emerald Insight—due to their comprehensive coverage of multidisciplinary, peer-reviewed studies relevant to sustainability, governance, and industrial performance. The Boolean search strings used were: *(“FOESG” OR “ESG framework” OR “sustainability performance” OR “strategic evaluation”) AND (“sugar industry” OR “agri-food sector” OR “agroindustry” OR “bioenergy industry”)*. The search covered the publication period 2020–2025, capturing the most recent advances in sustainability integration, ESG disclosure, and performance evaluation across agri-industrial sectors.

Results and Discussion

Thematic Synthesis of FOESG Dimensions

The FOESG concept emphasizes systemic interconnections—how financial capability and operational excellence serve as enabling factors for environmental protection and social well-being, while governance acts as the central coordinating mechanism ensuring transparency, accountability, and ethical management (Bansal & Desai, 2023). This integration reflects a shift from static sustainability reporting toward a dynamic, performance-based assessment model that aligns strategic, economic, and societal goals.

1. Financial Capability:

Financial resilience enables sustained investment in cleaner technologies and innovation. Strong financial governance correlates positively with superior sustainability outcomes, confirming that financial stability underpins both environmental and social initiatives (OECD, 2024). This finding aligns with the Resource-Based View (RBV), where financial resources act as strategic assets enabling ecological transition (Barney, 1991).

2. Operational Capability:

Operational efficiency—through digital transformation, automation, and cleaner production—emerged as the most researched FOESG component. Studies by Kumar and Singh (2023) demonstrate that process innovation directly improves both environmental and financial outcomes, reinforcing the interdependence between operational and environmental dimensions.

3. Environmental Performance:

Environmental performance remains central to sustainability research, emphasizing carbon reduction, water stewardship, and waste management (Tadesse et al., 2023). Integration of governance mechanisms strengthens accountability and ensures measurable progress toward national and international sustainability targets (IESR, 2024).

4. Social Performance:

Social inclusivity—including labor rights, gender equality, and community engagement—has gained attention as a key driver of stakeholder trust and corporate legitimacy (Freeman, 1984). The shift from philanthropy to shared value creation reflects a transformation in how social impact is embedded into corporate strategy.

5. Governance:

Governance acts as the integrative hub that ensures alignment among the four other FOESG dimensions. Effective governance frameworks improve transparency, compliance, and stakeholder confidence, thereby institutionalizing ethical decision-making and strategic accountability (OECD, 2024; Lozano, 2018).

FOESG Strategic Performance Framework

The resulting FOESG Strategic Performance Framework conceptualizes a circular model where governance occupies the central integrative role (see Figure 1).



Figure 1. FOESG Strategic Performance Framework

This circular interdependence represents a paradigm shift from linear sustainability reporting toward dynamic performance integration, aligning with current paradigms in *Business Strategy and the Environment* and *Journal of Cleaner Production* emphasizing governance-driven sustainability transformation.

Conclusion

The systematic literature review (SLR) revealed that research from 2020 to 2025 remains fragmented across individual ESG dimensions, with limited integration of financial and operational aspects. Through qualitative synthesis and bibliometric mapping, this study identified five core clusters—operational efficiency, clean production, ESG disclosure, corporate governance, and social responsibility—reflecting a gradual but incomplete transition toward integrated sustainability evaluation in the sugar sector.

Future Research Directions

To advance this emerging field, future studies should:

1. Develop quantitative and hybrid models.

2. Explore cross-sectoral applications of the FOESG framework across high-impact industries such as palm oil, bioethanol, and mining.
3. Integrate AI-based sustainability analytics and digital governance platforms.
4. Examine policy-level implications, particularly how regulatory structures and incentive mechanisms can enhance governance quality and transparency in agri-industrial sectors.

Acknowledgment

The author expresses sincere gratitude to academic colleagues and the State University of Jakarta for institutional and technical support. Special appreciation is extended to experts involved in peer debriefing for enhancing methodological rigor and conceptual clarity.

References

- Bansal, S., & Desai, R. (2023). Corporate sustainability practices in agribusiness: A governance perspective. *Journal of Sustainable Enterprises*, 11(2), 56–74. <https://doi.org/10.1016/j.jse.2023.06.005>.
- Bansal, P., & Desai, S. (2023). Revisiting corporate sustainability integration: The evolving role of governance and performance linkages. *Business Strategy and the Environment*, 32(1), 112–126. <https://doi.org/10.1002/bse.3261>.
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. <https://doi.org/10.1177/014920639101700108>.
- Bătae, O. M., Dragomir, V. D., & Feleagă, L. (2021). The impact of ESG factors on firm value: Empirical evidence from emerging markets. *Sustainability*, 13(17), 9788. <https://doi.org/10.3390/su13179788>.
- Elkington, J. (1998). *Cannibals with forks: The triple bottom line of 21st century business*. Oxford: Capstone Publishing.
- Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston: Pitman.
- IESR. (2024). *Sugar and cooking oil processing industry workshop: Emission reduction policy and industrial emission calculation*. Institute for Essential Services Reform..
- IESR. (2024). *Sustainable energy transition and industrial competitiveness in Southeast Asia*. Institute for Essential Services Reform.
- Kumar, V., & Singh, R. (2023). Cleaner production pathways in sugarcane-based industries: Toward a circular economy. *Journal of Cleaner Production*, 425, 138542. <https://doi.org/10.1016/j.jclepro.2023.138542>.
- Lozano, R. (2018). Sustainable business models: Providing a more holistic perspective. *Business Strategy and the Environment*, 27(8), 1159–1172. <https://doi.org/10.1002/bse.2056>.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2020). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine*, 6(7), e1000097.
- OECD. (2024). *Corporate governance and ESG disclosure in emerging economies*. Paris: OECD Publishing.
- OECD / FAO. (2025). *OECD–FAO Agricultural Outlook 2025–2034*. OECD Publishing. <https://doi.org/10.1787/601276cd-en>.
- Rahman, A., Hasan, M., & Chowdhury, S. (2024). Sustainable supply chain practices in the sugar industry under climate risk: An integrated RBV and dynamic capabilities perspective. *Sustainability*, 16(3), 1452. <https://doi.org/10.3390/su16031452>.
- Rahman, S., Alam, M., & Hassan, M. (2024). ESG performance and firm resilience: Evidence from emerging economies. *Sustainability*, 16(3), 1984. <https://doi.org/10.3390/su16031984>.
- Rezaee, Z., & Tuo, L. (2019). Are the quantity and quality of sustainability disclosures associated

with the innate and discretionary earnings quality? *Journal of Business Ethics*, 155(3), 763–786. <https://doi.org/10.1007/s10551-017-3539-9>

Tadesse, H., Mekonnen, G., & Alemu, S. (2023). Environmental sustainability in the sugar industry: Challenges and opportunities. *Environmental Economics Review*, 29(3), 112–128.

Tadesse, T., Mekonnen, D., & Alemu, M. (2023). Agricultural governance and the sustainability of sugarcane production in developing economies. *Agricultural Systems*, 208, 103700. <https://doi.org/10.1016/j.agsy.2023.103700>.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), 207–222. <https://doi.org/10.1111/1467-8551.00375>.

UNEP. (2024). *Circular economy in agri-processing sectors*. Nairobi: United Nations Environment Programme.

World Economic Forum. (2025). *The future of sustainable food industries: Integrating ESG into supply chains*. Geneva: WEF.

World Economic Forum. (2024, February). Environmental protection and sustainable food production in the Cerrado could create \$72 bn for Brazil. Retrieved from <https://www.weforum.org/press/2024/02/environmental-protection-and-sustainable-food-production-in-the-cerrado-could-create-72bn-for-brazil-says-new-report>

Yadav, V., & Patel, H. (2024). Social sustainability and rural welfare in sugarcane farming. *Asia-Pacific Development Journal*, 31(1), 77–95.

EDUCATION

Scope : Education

Article ID : 301

EMPOWERING SMART STUDENTS THROUGH DIGITAL PROJECT-BASED LEARNING: TRANSFORMING CRAFT EDUCATION FOR SUSTAINABLE CITIES

Karimulloh*, Khaerudin, and Eveline Siregar

Educational Technology, Faculty of Education, State University of Jakarta, Indonesia

E-mail: *karimulloh@mhs.unj.ac.id

Abstract

In 21st-century education, creativity and sustainability are vital for preparing students to contribute to innovative and sustainable communities. However, Indonesian Craft education (Prakarya) remains teacher-centered and exam-driven, limiting meaningful exploration. This study implemented a digital Project-Based Learning (PjBL) model integrating Padlet, Canva, and Google Classroom with 43 Grade VIII students in Bekasi. Data from Torrance-based rubrics, observations, portfolios, and interviews revealed significant gains in fluency, flexibility, originality, and elaboration ($p < .001$, medium to significant effects). Observations also showed higher engagement and collaboration. Overall, Craft education can serve as a transformative platform for fostering creativity, sustainability, and digital literacy, aligning classroom practice with global frameworks. The results highlight the potential of digital tools to create inclusive and student-centered learning experiences, supporting teachers in transforming traditional instruction toward creativity-based and future-ready education.

Keywords: Project-Based Learning; Craft Education; Creativity; Sustainability; Digital Literacy

Introduction

Modern education emphasizes creativity, collaboration, and digital literacy (OECD & Scott, 2015), with creativity essential for innovation and sustainability (Plucker, 2021; Kaufman & Beghetto, 2023). Indonesia's curriculum promotes autonomy and sustainability, positioning Craft (Prakarya) for creative, project-based learning (Sadiyah & Setyawan, 2025). Yet instruction remains exam-oriented and teacher-centered (Craft, 2003). PjBL, grounded in constructivist theory (Vygotsky & Piaget), enhances inquiry and reflection (Bell, 2010; Thomas, 2000). Evidence also shows that digital PjBL strengthens creativity and motivation (Kaya et al., 2023). However, few studies address Indonesian Craft learning (Yudiana et al., 2024). This study develops and tests a digital PjBL model to improve student creativity fluency, flexibility, originality, and elaboration—bridging global innovation and local needs.

Method

A quasi-experimental design with 43 Grade VIII students from SMP Tahta Syajar, Bekasi, was implemented. Participants were divided into experimental ($n = 22$) and control ($n = 21$) groups, consistent with the formal operational stage (Piaget, 1972). Creativity was measured using

a Torrance-based rubric assessing fluency, flexibility, originality, and elaboration (Torrance, 1974; Ding & Quan, 2021; Kaya et al., 2023). Collaboration and engagement were observed (Blumenfeld et al., 1991; Han, 2022), while motivation and digital literacy were assessed through questionnaires (Moya & Camacho, 2024; van Laar et al., 2020).

The experimental group applied digital Project-Based Learning (PjBL) through Padlet for brainstorming (Tang et al., 2022), Canva for design (Ruswandi et al., 2024), and Google Classroom for collaboration (Kim, 2024), while the control group followed conventional instruction. The intervention ran for six weeks (12 sessions). Data were analyzed using SPSS v27 (descriptive, t-test, ANCOVA) for rigor and validity (Thangavel et al., 2025).

Result and Discussion

Descriptive results showed that the experimental group outperformed the control group across all creativity dimensions, with the largest gains in fluency and elaboration. Independent- samples t-tests confirmed significant differences ($p < .001$, $d = 0.74\text{--}0.81$), which remained after controlling for initial digital literacy using ANCOVA. These quantitative results were reinforced by classroom observations showing more active brainstorming, diverse outputs, and constructive peer feedback in the experimental group.

These outcomes demonstrate the consistency between quantitative gains and observed creative behaviors, confirming the pedagogical robustness of digital PjBL.

Table 1. Descriptive Statistics of Creativity Scores (Pre- and Post-Test)

Creativity Dimension	Control Group (M ± SD)	Experimental Group (M ± SD)	Mean Difference
Fluency	67.2 ± 6.1	82.5 ± 5.7	+15.3
Flexibility	65.4 ± 7.0	79.1 ± 6.4	+13.7
Originality	66.8 ± 6.5	81.3 ± 5.9	+14.5
Elaboration	64.5 ± 6.8	82.7 ± 5.5	+18.2

These findings confirm that digital PjBL effectively enhances creativity in Craft learning, supporting prior evidence linking PjBL with engagement, motivation, and digital competence (Eliaumra et al., 2025). Each platform contributed distinctively: Padlet encouraged fluency through collective brainstorming, Canva enhanced elaboration via iterative design, and Google Classroom strengthened flexibility and collaboration through structured peer feedback. Creativity, as theorized by Torrance (1974) and Runco (2014), can be cultivated through guided discovery, aligning with constructivist perspectives (Vygotsky & Piaget), emphasizing interaction, reflection, and problem-solving. These findings also resonate with global frameworks (OECD & Scott, 2015), illustrating how Craft education can bridge creativity, sustainability, and digital literacy within local contexts (Tan & Chen, 2022; Zhan et al., 2023).

Although the study involved only 43 students over a six-week period, the model demonstrates scalability for classroom innovation and teacher professional development. Future studies should extend implementation across schools, integrate adaptive digital tools, and examine long-term impacts on creative confidence and sustainability-oriented problem-solving.

Conclusion

Digital PBL effectively enhanced students' creativity across the dimensions of fluency, flexibility, originality, and elaboration. Learners using Padlet, Canva, and Google Classroom exhibited greater engagement, collaboration, and reflective thinking compared to traditional instruction. These outcomes demonstrate that integrating digital PjBL into Craft education

promotes inquiry-based learning and fosters the competencies envisioned in Merdeka Belajar. For educators, this model offers a replicable approach to creativity-oriented instruction. Policymakers should, in turn, strengthen digital infrastructure and teacher training to ensure the sustainable adoption of this approach. The findings reinforce constructivist learning principles and align with OECD Education 2030 and UNESCO's Futures of Education agendas. Future research should involve larger cohorts, extended duration, and emerging technologies—such as AI, AR, and VR—to sustain innovation in creative education.

Acknowledgment

The authors would like to thank SMP Tahta Syajar, Bekasi, for the opportunity and support given during the research process. We are especially grateful to the students who participated with such energy and creativity throughout the project. We also acknowledge the support of Jakarta State University, whose academic guidance and institutional support made this study possible.

References

- Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39–43. <https://doi.org/10.1080/00098650903505415>
- Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, 26(3–4), 369–398. <https://doi.org/10.1080/00461520.1991.9653139>
- Ding, H., & Quan, G. (2021). How and When Does Follower's Strengths-Based Leadership Relate to Follower Innovative Behavior: The Roles of Self-Efficacy and Emotional Exhaustion. *The Journal of Creative Behavior*, 55(3), 591–603. <https://doi.org/10.1002/jocb.473>
- Eliaumra, E., Samaela, D. P., Novayanti Gala, I., Ferawati Rurua, S., & Akib, K. (2025). Enhancing Creative Thinking Skills Through Digital Literacy-Based PjBL Model Assessment: A Quasi-Experimental Study. *Journal of Neonatal Surgery*, 14(10S), 342–354. <https://doi.org/10.52783/jns.v14.2803>
- Han, F. (2022). Recent Development in University Student Learning Research in Blended Course Designs: Combining Theory-Driven and Data-Driven Approaches. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.905592>
- Kaufman, J. C., & Beghetto, R. A. (2023). Where is the When of Creativity?: Specifying the Temporal Dimension of the Four Cs of Creativity. *Review of General Psychology*, 27(2), 194–205. <https://doi.org/10.1177/10892680221142803>
- Kaya, D., Kutluca, T., & Dağhan, G. (2023). Transforming Education with Augmented Reality, Metaverse and Virtual Reality Technologies in the 21st Century. *Hacettepe University Journal of Education*. <https://doi.org/10.16986/HUJE.2023.503>
- Kim, J. (2024). Leading teachers' perspective on teacher-AI collaboration in education. *Education and Information Technologies*, 29(7), 8693–8724. <https://doi.org/10.1007/s10639-023-12109-5>
- Moya, S., & Camacho, M. (2024). Leveraging AI-powered mobile learning: A pedagogically informed framework. *Computers and Education: Artificial Intelligence*, 7, 100276. <https://doi.org/10.1016/j.caeai.2024.100276>
- OECD. (2020). *Education 2030: Learning compass and skills for the future*. OECD. <https://www.oecd.org/education/2030>
- Piaget, J. (2000). *The psychology of the child*. Basic Books. (Original work published 1969).
- Plucker, J.A. (2017). *Creativity and Innovation: Theory, Research, and Practice* (1st ed.). Routledge. <https://doi.org/10.4324/9781003233930>

- Runco, M. A. (2014). *Creativity: Theories and themes: Research, development, and practice* (2nd ed.). Elsevier / Academic Press.
- Ruswandi, R., Gumelar, W. S., Ermaya, A. S., & Ginanjar, G. (2024). The effectiveness of project-based learning by using Canva application on students' descriptive writing achievement. *EduLite: Journal of English Education, Literature, and Culture*, 9 (2), 1–20. <http://dx.doi.org/10.30659/e.9.2.1-20>
- Sadiyah, A., & Setyawan, A. B. (2025). The impact of creativity and PKWU learning achievement on entrepreneurial interest among high school students. *Communications in Humanities and Social Sciences*, 5(1), 1–7. <https://doi.org/10.21924/chss.5.1.2025.90>
- Scott, C. L. (2015). *The futures of learning 2: What kind of learning for the 21st century?* UNESCO Education Research and Foresight Working Papers, No. 14. UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000242996>
- Tan, J. SH., & Chen, W. (2022). Peer feedback to support collaborative knowledge improvement: What kind of feedback feed-forward? *Computers & Education*, 187, 104467. <https://doi.org/10.1016/j.compedu.2022.104467>
- Tang, C., Mao, S., Naumann, S. E., & Xing, Z. (2022). Improving student creativity through digital technology products: A literature review. *Thinking Skills and Creativity*, 44, 101032. <https://doi.org/10.1016/j.tsc.2022.101032>
- Thangavel, S., K, S., & K, S. (2025b). Revolutionizing Education Through Augmented Reality (AR) and Virtual Reality (VR): Innovations, Challenges and Future Prospects. *Asian Journal of Interdisciplinary Research*, 1–28. <https://doi.org/10.54392/ajir2511>
- Thomas, J. W. (2000). *A review of research on project-based learning*. Autodesk Foundation. https://tecfa.unige.ch/proj/eteach-net/Thomas_researchreview_PBL.pdf.
- Torrance, E. P. (1974). *Torrance tests of creative thinking: Norms-technical manual*. Scholastic Testing Service.
- van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2020). Determinants of 21st-Century Skills and 21st-Century Digital Skills for Workers: A Systematic Literature Review. *Sage Open*, 10(1). <https://doi.org/10.1177/2158244019900176>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.
- Yudiana, I. K. E., Nirmayani, L. H., & Sari, N. M. D. S. (2024). Project-Based Learning Students Worksheets on Students' Critical Thinking Skills and Independence in Social Studies Learning Courses. *Thinking Skills and Creativity Journal*, 7(1), 131–138. <https://doi.org/10.23887/tscj.v7i1.75534>
- Zhan, Y., Yan, Z., Wan, Z. H., Wang, X., Zeng, Y., Yang, M., & Yang, L. (2023). Effects of online peer assessment on higher-order thinking: A meta-analysis. *British Journal of Educational Technology*, 54(4), 817–835. <https://doi.org/10.1111/bjet.13310>

EDUCATIONAL NONPROFIT LEADERSHIP AND DIGITAL TRANSFORMATION OF DEPOK CITY LIBRARY TOWARDS SMART SUSTAINABLE CITIES

Khairunnisa Putri Alif ^{1*}, Eliana Sari ², and Neti Karnati¹

¹*Education Management, Jakarta State University, Jakarta, Indonesia*

²*Faculty of Education, Jakarta State University, Jakarta, Indonesia*

E-mail: *khairunnisa_1119925008@mhs.unj.ac.id

Abstract

This study examines the role of educational nonprofit leadership in the digital transformation of the Depok City Library to advance Sustainable Development Goals (SDG 4 and SDG 11) toward smart and sustainable cities. Using a qualitative library research method, this paper synthesizes findings from scholarly sources on nonprofit leadership, digital education, and sustainability policies. The analysis reveals that nonprofit educational leaders play a strategic role in promoting digital inclusion, strengthening intersectoral collaboration, and embedding sustainability values in library management. Transformational and collaborative leadership models are identified as the most effective in ensuring equitable access to digital knowledge and fostering community participation in the smart city agenda. By positioning the Depok City Library as a case of social innovation, this study underscores the importance of leadership that aligns technological transformation with educational equity and long-term urban resilience.

Keywords: Nonprofit, Leadership, Digital, Transformation, Sustainability

Introduction

The development of digital technology in the 21st century has brought significant changes in various areas of life, including education and knowledge management. Digital transformation requires not only technological adaptation, but also visionary and collaborative leadership in managing educational institutions, both formal and non-formal. One of the institutions directly affected by this process is the library, which now no longer functions solely as a place for storing and lending books, but has transformed into a center for digital literacy and learning innovation (Rahmawati, 2021). In the Indonesian context, Depok City Library is a concrete example of a public institution that is striving to adapt to the digital era through the application of nonprofit leadership in the field of education. As a public service institution, this library plays an important role in supporting the local government's agenda to create a smart city and a sustainable city. Through the digitization of services and technology-based management, the Depok City Library seeks to expand public access to knowledge resources, improve digital literacy, and strengthen community participation in knowledge-based development (Suhendra, 2023).

Leadership is a determining factor in the success of the digital transformation process. According to Inceoglu et al. (2018), effective leadership behavior not only improves organizational performance but also the well-being and motivation of members. In the context of educational

non-profit organizations, transformational and collaborative leadership is very important because it can inspire members of the organization and the community to work together to achieve common goals. Transformational leaders have a long-term vision, encourage innovation, and create an environment that is adaptive to technological change (Sari & Kartika, 2020).

Furthermore, collaborative leadership encourages partnerships between the government, civil society, and digital literacy communities. Through this collaboration, resources can be mobilized more effectively to support equitable access to information and education. This is in line with the idea of sustainable development (Sustainable Development Goals/SDGs), particularly goals 4 (quality education) and 11 (sustainable cities and communities), which emphasize the importance of educational innovation to improve the quality of life of communities (UNESCO, 2020). Thus, the role of nonprofit leadership in education is very strategic in building a learning ecosystem that is oriented towards sustainability. The Depok City Library as a case study shows how leadership based on social values, collaboration, and innovation can bridge the digital divide and strengthen urban social resilience. Based on this background, this study aims to examine the role of non-profit educational leadership in the digital transformation of the Depok City Library and its contribution to smart and sustainable city development. This study is expected to provide a conceptual and empirical overview of effective leadership models for addressing the challenges of digital transformation in the context of public educational institutions in Indonesia.

Method

The approach used in this literature study is a qualitative approach using the library research method. Library research is a research method conducted through systematic review of various literature sources relevant to the research topic, such as books, scientific journals, research reports, and policy documents (Mardalis, 1999). The data collection technique used is documentation, which involves identifying and analyzing data sourced from literature (Arikunto, 2010).

Result and Discussion

The researchers conducted a literature search relevant to the title of the literature study using the Google database. In the initial stage, 1.810 articles were identified by the researchers. All of these articles were then divided into two groups: accepted articles and rejected articles. This resulted in 441 articles, which were then screened based on their relevance to the title of the literature study. The screening results showed that only 36 articles were suitable, and after eligibility was determined, only 5 articles were found to be suitable for use in the literature study. The literature selection process can be visualized as follows: Identification (1.810 articles) → Screening (441 articles) → Eligibility (36 articles) → Inclusion (5 final articles). These five articles were then analyzed in depth using a thematic approach to identify patterns, similarities, and key contributions related to non-profit educational leadership in the digital transformation of the Depok City Library towards a smart and sustainable city.

Table 1. Summary of Qualitative Studies on Educational NonProfit Leadership and Digital Transformation of Depok City Library Towards Smart Sustainable Cities

Author(s)	Title	Qualitative Method	Main Findings / Relevance to the Study
Battulga Buyannemekh, Mila Gasco-Hernandez, & J. Ramon Gil-Garcia (2024)	Fostering Smart Citizens: The Role of Public Libraries in Smart City Development	Qualitative case study using in-depth interviews with librarians and city officials	Public libraries act as agents of smart city development through technology training, innovation hubs, and multi-stakeholder collaboration. Leadership in libraries fosters community digital literacy and civic participation. The National Library's leadership promotes social inclusion as the foundation of digital transformation, expanding access to vulnerable groups and strengthening libraries' roles as nonprofit educational institutions supporting the SDGs. The library integrates digital services, literacy workshops, and community partnerships. Librarians act as community leaders who drive innovation and promote inclusive education through digital access.
Reza Mahdi, Muakibatul Hasanah, & Andi Asari (2020)	Social Inclusion-Based Library Transformation: The National Library of Indonesia's Role to Support SDGs	Qualitative case study (interviews and document analysis)	
Rr. Iridayanti Kurniasih & Rahmat Setiawan Saefullah (2021)	Social Inclusion as a Transformation of Services at Karanganyar Regional Library	Descriptive qualitative (interviews, observations, and documentation)	
Firly Erya Faldilal Nuraini & Agus Widiyarta (2025)	Strategic Implementation of Social Inclusion-Based Library Transformation (TPBIS) in East Java	Descriptive qualitative using Fred R. David's strategic implementation framework	The success of TPBIS programs depends on strategic vision, policy alignment, resource allocation,

Dzakkiyah Addawiyah Marpaung Franindya Purwaningtyas (2025)	& Implementation of TPBIS Based on KPI at TBM Teras Literasi Mutiar Langit Biru	Descriptive qualitative (observation, interviews, and documentation)	and cross- sector collaboration. Leadership commitment and strategic management are key drivers of sustainable digital transformation. The TPBIS implementation improves community engagement, technology-based literacy services, and advocacy. Nonprofit educational leaders play a central role in fostering digital inclusion and sustainable community empowerment
--	---	--	---

Table 1 presents five qualitative studies that highlight how nonprofit and educational leadership play a pivotal role in the digital transformation of library institutions toward the realization of smart and sustainable cities. These studies consistently emphasize that effective leadership is the driving force behind innovation, collaboration, and the creation of inclusive digital learning environments. Buyannemekh, Gasco-Hernandez, and Gil-Garcia (2024) demonstrate that libraries are no longer static repositories of information but have evolved into community-based innovation hubs. Their study shows how leadership practices that encourage digital literacy, stakeholder partnerships, and citizen engagement can transform libraries into enablers of smart city development. This reflects the importance of adaptive leadership that aligns technology integration with social needs. Mahdi, Hasanah, and Asari (2020) explore the National Library of Indonesia’s transformation based on social inclusion principles. Their findings reveal that strong institutional leadership, combined with advocacy for equal access, strengthens the role of libraries as nonprofit educational institutions supporting the Sustainable Development Goals (SDGs). This aligns with the idea that digital transformation in public organizations must be anchored in equity and inclusivity. Similarly, Kurniasih and Saefullah (2021) find that regional libraries in Indonesia can achieve meaningful transformation through leadership that prioritizes collaboration, local innovation, and community participation. Their study identifies librarians as community leaders who drive change by fostering literacy and creativity through technology based programs. Further, Nuraini and Widiyarta (2025) highlight how strategic leadership frameworks vision formulation, policy integration, and resource management support the successful implementation of social inclusion-based programs in East Java. This strategic perspective ensures that digital transformation is not limited to technology adoption but extends to organizational culture and sustainability planning. Finally, Marpaung and Purwaningtyas (2025) provide evidence from a community reading center that leadership within nonprofit educational spaces facilitates the empowerment of local communities. Their findings emphasize the role of nonprofit leaders in mobilizing digital resources, training programs, and advocacy initiatives to reduce the digital divide and foster sustainable urban resilience.

Overall, these studies reinforce that nonprofit educational leadership is not merely administrative but transformative. It combines vision, empathy, and collaboration to ensure that

digital innovation contributes to social inclusion and sustainable urban development. In the context of Depok City Library, such leadership can serve as a catalyst for building a digitally literate, equitable, and environmentally conscious society.

Conclusion

This study concludes that educational nonprofit leadership plays a crucial role in driving the digital transformation of the Depok City Library toward an innovative and sustainable city model. Effective leadership fosters collaboration, digital inclusion, and innovation, aligning technology with social and educational goals. Transformational and collaborative leadership styles are proven to be the most effective in ensuring that libraries evolve into inclusive digital learning hubs that strengthen community resilience and sustainability.

Acknowledgment

The authors would like to express their sincere gratitude to the Faculty of Education, Jakarta State University, for its academic guidance and continuous support throughout this study. Special thanks are also extended to the Depok City Library and the local literacy community for their inspiration in shaping this research topic.

References

- Arikunto, S. (2010). *Prosedur Penelitian: Suatu Pendekatan Praktik*. Jakarta: Rineka Cipta.
- Buyannemekh, B., Gasco-Hernandez, M., & Gil-Garcia, J. R. (2024). Fostering Smart Citizens: The Role of Public Libraries in Smart City Development. *Sustainability*, 16(2), 112–128.
- Inceoglu, I., Thomas, G., Chu, C., Plans, D., & Gerbasi, A. (2018). Leadership behavior and employee well-being: An integrated review. *The Leadership Quarterly*, 29(1), 179–202.
- Kurniasih, R. I., & Saefullah, R. S. (2021). Inklusi Sosial sebagai Transformasi Layanan di Perpustakaan Daerah Karanganyar. *Jurnal IPI (Ikatan Pustakawan Indonesia)*, 6(2), 45–57.
- Mahdi, R., Hasanah, M., & Asari, A. (2020). Social Inclusion-Based Library Transformation: The National Library of Indonesia's Role to Support SDGs. *Library Philosophy and Practice (e-journal)*, Paper 6028.
- Mardalis. (1999). *Metode Penelitian: Suatu Pendekatan Proposal*. Jakarta: Bumi Aksara.
- Nuraini, F. E. F., & Widiyarta, A. (2025). Strategic Implementation of Social Inclusion-Based Library Transformation (TPBIS) in East Java. *Jurnal Transformasi Digital Pendidikan*, 3(1), 77–91.
- Rahmawati, D. (2021). Nonprofit Governance in Public Library Innovation. *Asian Journal of Education and Development*, 3(4), 45–58.
- Sari, E., & Kartika, W. (2020). Transformational Leadership in Digital Literacy Programs. *Journal of Educational Management*, 7(1), 23–34.
- Suhendra, T. (2023). Educational Leadership and Urban Sustainability. *Indonesian Journal of Smart Cities*, 6(1), 91–105.
- UNESCO. (2020). *Education for Sustainable Development Goals: Learning Objectives*. Paris: United Nations Educational, Scientific and Cultural Organization.
- Aharony, N. (2021). Digital transformation and leadership in libraries: A systematic literature review. *Journal of Librarianship and Information Science*, 53(4), 523–538.
- Bryson, J. M., Crosby, B. C., & Bloomberg, L. (2017). Public value governance: Moving beyond traditional public administration and the New Public Management. *Public Administration Review*, 77(4), 445–456.
- Dener, C., Nii-Aponsah, H., Ghunney, L., & Johns, K. (2021). *Digital Government Readiness Assessment Toolkit*. World Bank Publications.
- Laužikas, M., & Miliūtė, A. (2020). Transformational leadership and sustainable innovation in

education. *Entrepreneurship and Sustainability Issues*, 7(4), 2909–2924.

Mikalef, P., Krogstie, J., Pappas, I. O., & Pavlou, P. (2020). Investigating the effects of big data analytics capabilities on firm performance: The mediating role of dynamic capabilities. *Information & Management*, 57(2), 103207.

Osborne, S. P. (2021). Public service logic and leadership for social innovation. *Public Management Review*, 23(7), 983–1001.

Rowley, J. (2016). Information professionals and digital leadership in the information society. *Library Hi Tech*, 34(4), 763–776.

Trench, D., & O'Donnell, P. (2023). Smart cities and public value: Rethinking leadership for urban innovation. *Journal of Urban Technology*, 30(1), 22–40.

Zhao, Y., & Hu, W. (2018). Nonprofit leadership and digital engagement: A global perspective. *Nonprofit Management & Leadership*, 29(3), 397–412

THE INFLUENCE OF SOCIO-DEMOGRAPHIC CHARACTERISTICS ON STUDENTS' ENVIRONMENTAL CONCERN IN JAKARTA

Andrea Vondra^{1*}, Sisean Baga¹, Robert Kurniawan², and Fidelia Fedora¹

¹*Sinar Dharma High School, Jakarta, Indonesia*

²*Statistics Polytechnic STIS, Jakarta, Indonesia*

E-mail: *andreavondra@smasinardharma.sch.id

Abstract

The global climate crisis demands a focused understanding of factors driving individual Environmental Concern (EC), especially among youth in Jakarta, where strong EC is vital for sustainable urban development. This study investigates the influence of specific socio-demographic characteristics and daily lifestyle patterns on EC among high school students. Employing a quantitative, cross-sectional survey design and multiple linear regression analysis on a sample of 475 students, the research assessed the predictive power of Gender, Grade Level, Parental Occupation, and Daily Transportation Mode. The main finding confirms that the socio-demographic profile is a highly significant predictor ($F(4,470)=191.875, p<0.001$). Daily Transportation Mode and Gender primarily shape the predictive model: female students demonstrate higher EC than their male peers, and crucially, reliance on less sustainable transport correlates strongly with lower internalized concern. The research concludes that individuals must target interventions in Jakarta toward gender and transportation behaviors to foster more substantial ecological commitment.

Keywords: Environmental concern, socio-demographics.

Introduction

The climate crisis presents an urgent, existential challenge on a global scale, demanding concerted efforts from governments, industries, and individuals alike. Individual behavior plays a central role in effective mitigation and adaptation strategies, as it is intrinsically linked to one's level of environmental concern (Hristova et al., 2025; Nayan et al., 2020; Zhao et al., 2025). As a large, rapidly growing metropolitan area in a developing country, Jakarta faces unique environmental pressures, making the cultivation of strong environmental concern among its population, particularly the youth, critically crucial for fostering sustainable urban development. This concern, however, is not a spontaneous phenomenon; instead, a confluence of personal and contextual factors shapes it (Diamantopoulos et al., 2003; Gómez-Carmona et al., 2022). A solid body of literature suggests that an individual's socio-demographic background and daily experiences significantly shape their perception of and attitude toward environmental issues.

While the general link between socio-demographic factors and environmental concern has been well established, specific insights tailored to the dynamic urban context of Jakarta's student population remain underexplored. This study is grounded in the theoretical understanding that socio-demographic variables serve as powerful proxies for life experiences, values, and exposure to environmental stimuli, thereby shaping pro-environmental attitudes. For instance, age is often associated with differences in future orientation and perceived vulnerability to ecological impacts,

while gender has been repeatedly linked to varying levels of environmental empathy and perceived risk (Baga et al., 2022; Fathonah & Nastiti, 2024; Heberlein, 2012). Therefore, this study aims to determine the socio-demographic characteristics of environmental concerns of students at Jakarta Senior High Schools.

Method

This study employed a quantitative, cross-sectional survey to investigate the relationship between high school students' socio-demographic characteristics and Environmental Concern (EC) in Jakarta (Cruz & Manata, 2020; Dunlap & Jone, 2002). A multistage sampling of four districts and nine schools, followed by quota and convenience sampling, yielded 475 students (189 males and 286 females) from Grades 10–12. The research team obtained ethical clearance and informed consent and collected data through a structured electronic questionnaire administered between September and October 2025. The instrument measured socio- demographics (age, gender, grade, parental occupation, transportation) and EC—internalized attitudes, affect, and effort toward water, energy, and waste management—on a 5-point Likert scale (Al-Rabaani & Al-Shuili, 2020; Gansser & Reich, 2023). Data analysis included descriptive statistics, ANOVA with post-hoc Tukey tests, assumption checks (Shapiro-Wilk), multicollinearity assessment (VIF), and effect sizes to quantify the variance explained by socio- demographic predictors (Privitera, 2018).

Result and Discussion

The researchers performed an analysis of variance (ANOVA) to test the overall model fit and to determine whether the combined socio-demographic variables significantly predicted students' Environmental Concern (EC). The results of the ANOVA, presented in the Table below, indicate that the regression model is statistically significant.

Table 1. ANOVA Test of Research

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9142,217	4	3205,706	191,875	<,001
	Residual	7602,743	470	15,354		
	Total	17159,061	474			

ANOVA results showed a highly significant F-ratio ($F(4,470) = 191.875, p < 0.001$), indicating that Age, Gender, Grade Level, and Daily Transportation Mode collectively explain a substantial portion of the variance in students' environmental concern (EC). The model accounted for 9,142.217 of the total 17,159.061 sum of squares, confirming strong explanatory power (Table 1). Multiple linear regression further assessed the contribution of each variable (Table 2), revealing that three of the four predictors significantly influence EC.

Table 2. Regression Coefficients for Socio-Demographic Predictors of Environmental Concern

Model	Unstandardized B	Coefficients Std. Error	Standardized coefficients Beta	t	sig.
(Constant)	85.140				
Gender (G)	3.372	.634	.141	5.221-	0.00
Grade Level (GL)	.284	.378	.019	.775	.441
Parental Occupation (PO)	-.577	.256	-.062	-2.253	.027
Daily Transportation Mode (DTM)	-.4119	.778	-.147	-5.350	.000

The regression results reveal that three out of the four socio-demographic variables significantly predict Environmental Concern, demonstrating differential impacts that warrant targeted discussion.

Gender and Daily Transportation Mode were the strongest predictors of Environmental Concern (EC). Female students reported higher EC, likely due to socialization fostering empathy and care, as well as traditional caregiving roles increasing sensitivity to ecological risks (Fathonah & Nastiti, 2024; Torkar et al., 2021). Women's environmental problems are also often more closely tied to local health and safety issues, reflecting their traditional social roles as family caregivers, which inherently heightens their perception of environmental risks (Gökmen, 2021).

Students using private vehicles showed lower EC, whereas those using public or active transport demonstrated higher concern, suggesting that daily mobility both reflects and reinforces environmental awareness through direct engagement with urban environmental challenges (Amin & Vyas, 2016). This relationship indicates a psychological mechanism underlying the internalization of behavior: when individuals, especially students, routinely choose unsustainable modes of transportation such as private vehicles, they are less likely to confront or attribute the negative environmental impacts of those choices to themselves (lower ascription of responsibility).

Parental Occupation also had a significant, though smaller, effect ($B = -0.577$, $p = 0.027$); students from higher-income or higher-status families tended to exhibit slightly lower EC, possibly due to materialistic lifestyles and symbolic "eco-friendly" behaviors (Dolonseda et al., 2024; Fairbrother, 2012). These findings find theoretical support in the Environmental Kuznets Curve (EKC) and the Post-Materialism Theory, both of which posit that environmental concern tends to increase with rising wealth. Research indicates that wealthier individuals tend to be slightly more environmentally conscious, but only on specific dimensions, and this often does not translate into a willingness to make material sacrifices or reduce consumption (Fairbrother, 2012). However, people with high incomes and good social status cannot consistently demonstrate environmental concern, as this is sometimes merely symbolic rather than a radical lifestyle change (Gifford & Nilsson, 2014).

In contrast, Grade Level was non-significant ($B = 0.284$, $p = 0.441$), likely because shared institutional contexts and uniform exposure to environmental information through social media and global news reduce differences across grades (Nguyen et al., 2024; Truc, 2024). The finding reinforces that differences in grade level do not significantly affect environmental awareness, as socio-institutional factors and collective media exposure exert greater influence on high school students' ecological awareness than grade level alone (Chao, 2024).

Conclusion

This study confirms that the socio-demographic profile of Jakarta high school students significantly predicts Environmental Concern (EC). Daily Transportation Mode and Gender are the strongest predictors, followed by Parental Occupation. Female students demonstrated higher environmental concern (EC), while students who used private vehicles showed lower levels of concern. Grade Level is non-significant, suggesting a limited cumulative impact of current curricula. These findings provide context-specific insights, identifying key groups for targeted environmental interventions in Jakarta. Future studies should adopt a broader socio-demographic perspective when examining ecological concerns across the Indonesian context. This expansion is vital, as it provides the necessary foundation for the government to develop effective and positive environmental policies.

Acknowledgment

We want to thank Sinar Dharma High School for its full support throughout this research process, both morally and materially.

References

- Al-Rabaani, A., & Al-Shuili, A. (2020). Environmental knowledge, attitudes, and behavior among Omani post-basic education students. *European Journal of Social Sciences*, 60(1), 29–38.
- Amin, S., & Vyas, S. (2016). Effects of transportation on environment. *International Journal of Advanced Research*, 4(11), 2127–2225. <https://doi.org/10.21474/ijar01/2073>
- Baga, S., Astuty, E. R., Astra, I. M., Budiaman, B., & Hasanah, U. (2022). Perilaku pro-lingkungan peserta didik berdasarkan media pembelajaran dan gender. *Jurnal Basicedu*, 6(5), 8368–8380. <https://doi.org/10.31004/basicedu.v6i5.3809>
- Chao, Y. L. (2024). Different tracks, same greenness? Environmental literacy models integrated with teachers' environmental education practices for academic vs. technical/vocational high school students. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2357922>
- Cruz, S. M., & Manata, B. (2020). Measurement of environmental concern: A review and analysis. *Frontiers in Psychology*, 11, 363. <https://doi.org/10.3389/fpsyg.2020.00363>
- Diamantopoulos, A., Schlegelmilch, B. B., Sinkovics, R. R., & Bohlen, G. M. (2003). Can socio-demographics still play a role in profiling green consumers? A review of the evidence and an empirical investigation. *Journal of Business Research*, 56(6), 465–480. [https://doi.org/10.1016/S0148-2963\(01\)00241-7](https://doi.org/10.1016/S0148-2963(01)00241-7)
- Dolonseda, H. P., Taroreh, J., & Arsana, I. K. S. (2024). Analyzing students' consumptive behavior: The impact of parental socio-cultural and economic factors. *Jurnal Inovasi Pendidikan Ekonomi (JIPE)*, 14(2), 193–200. <https://doi.org/10.24036/011315520>
- Dunlap, R. E., & Jone, R. (2002). Environmental concern: Conceptual and measurement issues. In R. E. Dunlap & W. Michelson (Eds.), *Handbook of environmental sociology* (pp. 482–524). Greenwood Press.
- Fairbrother, M. (2012). Rich people, poor people, and environmental concern: Evidence across nations and time. *European Sociological Review*, 29(5), 910–922. <https://doi.org/10.1093/esr/jcs068>
- Fathonah, N., & Nastiti, A. (2024). How does gender affect pro-environmental behaviors? The case of a university in Bandung, Indonesia. *E3S Web of Conferences*, 485, 07004. <https://doi.org/10.1051/e3sconf/202448507004>
- Gansser, O. A., & Reich, C. S. (2023). Influence of the new ecological paradigm (NEP) and environmental concerns on pro-environmental behavioral intention based on the theory of planned behavior (TPB). *Journal of Cleaner Production*, 382, 134629. <https://doi.org/10.1016/j.jclepro.2022.134629>

- Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review. *International Journal of Psychology*, 49(3), 141–157. <https://doi.org/10.1002/ijop.12034>
- Gökmen, A. (2021). The effect of gender on environmental attitude: A meta-analysis study. *Journal of Pedagogical Research*, 5(1), 243–257. <https://doi.org/10.33902/JPR.2021167799>
- Gómez-Carmona, D., Marín-Dueñas, P. P., Tenorio, R. C., Domínguez, C. S., Muñoz-Leiva, F., & Liébana-Cabanillas, F. J. (2022). Environmental concern as a moderator of information processing: An fMRI study. *Journal of Cleaner Production*, 369, 133306. <https://doi.org/10.1016/j.jclepro.2022.133306>
- Heberlein, T. A. (2012). Navigating environmental attitudes. *Conservation Biology*, 26(4), 583–585. <https://doi.org/10.1111/j.1523-1739.2012.01892.x>
- Hristova, V., Haralampiev, K., Vlaev, I., & Karabeliova, S. (2025). Predicting pro-environmental behavior: The leading influence of environmental attitudes. *Behavioral Sciences*, 15(3), 291. <https://doi.org/10.3390/bs15030291>
- Nayan, N., Hashim, M., Mahat, H., Saleh, Y., & Norkhaidi, S. B. (2020). Youth climate change mitigation practices and adaptation in Malacca State, Malaysia. *Review of International Geographical Education Online*, 10(2), 58–71. <https://doi.org/10.33403/rigeo.545819>
- Nguyen, J., Abdullah, A., & Park, J.-H. (2024). The influence of social media on environmental news reporting and public discourse in China. *Khulna University Studies*, 21(2), 181–189. <https://doi.org/10.53808/kus.2024.21.02.1212-ss>
- Privitera, G. J. (2018). *Essential statistics for the behavioral sciences* (2nd ed.). Sage Publications.
- Torkar, G., Debevec, V., Johnson, B., & Manoli, C. C. (2021). Assessing children's environmental worldviews and concerns. *Center for Educational Policy Studies Journal*, 11(1), 49–65. <https://doi.org/10.26529/cepsj.793>
- Truc, L. T. (2024). Greening the future: How social networks and media shape youth's eco-friendly purchases. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(4), 100410. <https://doi.org/10.1016/j.joitmc.2024.100410>
- Zhao, J., Li, Y., Wu, T., & Jiang, W. (2025). Can public environmental concern drive changes in residents' green consumption behavior? *Sustainability*, 17(12), 5352. <https://doi.org/10.3390/su17125352>

INTEGRATING FLOOD PREPAREDNESS AND ECOLOGICAL CITIZENSHIP IN PRIMARY EDUCATION: EVIDENCE FROM EAST KALIMANTAN, INDONESIA

Arum Sekar Kedhaton^{1*} and Prince Clinton Immanuel Christian Damanik²

¹Department of Geography Education, Mulawarman University, Samarinda, Indonesia

²Department of Primary Teacher Education, Jakarta State University, Jakarta, Indonesia

E-mail: *arumsekar@fkip.unmul.ac.id

Abstract

This study investigates the relationship between flood preparedness and the development of ecological citizenship in Primary education through a mixed-methods approach. Conducted in Loa Janan Ilir District, East Kalimantan, the quantitative strand involved 110 students from three schools selected through proportional stratified random sampling. The qualitative strand comprised a literature-based inquiry into ecological citizenship, emphasizing environmental responsibility and civic engagement. Findings show that students in schools near rivers demonstrated stronger experiential knowledge of floods, while those farther from rivers exhibited higher disaster preparedness. Integrating empirical results with ecological citizenship theory indicates that both direct environmental experience and structured civic-ecological learning are essential for fostering resilience and responsibility in young learners.

Keywords: Ecological Citizenship; Disaster Education; Flood Preparedness; Primary Education; Flood Disaster

Introduction

East Kalimantan is classified as a high-risk region for flooding due to the presence of the Mahakam River and its tributary network, as well as land-use change pressures in the watershed, which trigger an increased extent of downstream inundation (Ardiansyah et al., 2021; Ariyaningsih & Shaw, 2022; Setiawan et al., 2020). Teaching and learning activities at 21 schools under the Samarinda City Education Office were disrupted by floods that inundated several areas. Students were forced to be sent home early or even have school activities entirely. These floods have affected five districts: Samarinda Utara, Sungai Pinang, Sambutan, Samarinda Sebrang, and Loa Janan Ilir (Fathur, 2020; Kedhaton & Krismondo, 2024). In the Loa Janan Ilir District, more than 3,000 students from three Primary schools were directly impacted by the flooding (Kedhaton, 2024). These three schools, namely SD Negeri 006, SD Negeri 009, and SD Negeri 010 Loa Janan Ilir, are considered highly disaster-prone. This vulnerability is attributed to the high frequency of flooding at their locations and their susceptible geographical positions (Kedhaton, 2024).

Primary school students are one of the communities most vulnerable to the impacts of flood disasters. This is because students in flood-prone areas often have low levels of knowledge and preparedness, making them susceptible to the effects of flooding (Saraswati et al., 2024). Floods disrupt learning and endanger health through structural damage, electrical hazards, and contamination (Septiningrum et al., 2022; Song et al., 2022). Hence, integrating disaster education into curricula is vital for building resilience rather than reactive responses, though many programs still emphasize procedures over critical and adaptive thinking (Aghaei et al., 2018; Masocha et

al., 2025). Preparedness is often seen merely as survival training, not as part of civic responsibility or environmental care. Evidence from the UK shows that outdoor and inquiry-based learning can strengthen pro-environmental attitudes and ecological citizenship from an early age (Christodoulou & Grace, 2025).

Preparedness practices in the field are often seen as an isolated set of survival skills, rather than as an embodiment of the responsibility and care of an active citizen for communal safety and environmental sustainability. However, disaster education holds a deep transformative potential. The concept of environmental citizenship education suggests that disaster preparedness is not merely about mastering techniques but also about a citizen's ethical understanding of their relationship with nature, emotional connection, and social responsibility towards the broader community. The engagement of Primary school students in the UK through outdoor and inquiry-based learning programs has been shown to strengthen pro-environmental attitudes and ecological citizenship from an early age (Christodoulou & Grace, 2025).

This is where the concept of ecological citizenship provides an important theoretical foundation for disaster education. This concept positions preparedness not merely as a technical skill, but as part of a citizen's responsibility towards environmental sustainability and the safety of their community. Environmental citizenship demands the active involvement of individuals in maintaining ecosystem balance through collective action rooted in ethical and social awareness (Činčera et al., 2020). Education plays a role in fostering ecological citizens who are active in mitigating climate change and managing natural disasters (del Castillo, 2022).

Method

This research was conducted in Loa Janan Ilir District, which is administratively located in Samarinda, East Kalimantan. The study took place in three Primary schools that are geographically situated both near and far from the river but experience a high frequency of flood events. The quantitative sample consisted of 110 students selected using the stratified random sampling method. The research employed a regional complex approach and was carried out from August to December 2024. Data collection techniques included observation, questionnaires, and literature study. The validity of the instruments was tested using the product-moment correlation, while reliability was tested using Cronbach's alpha with a 5% significance level. Data analysis was conducted using a quantitative approach with non-statistical frequency tables. The qualitative strand comprised a literature based inquiry into ecological citizenship, emphasizing environmental responsibility and civic engagement.

Result and Discussion

A student's experience is considered good if it meets several parameters when facing a flood disaster. These parameters include not feeling afraid, traumatized, or worried if a flood occurs again; having knowledge about the vulnerability of the Loa Janan Ilir area to floods; knowing the actions to take during a flood; and understanding the types of damage that floods can cause. Table 1 displays the percentage of students' experiences in facing flood disasters at schools located far from and near the river.

Table 1. Percentage of Primary School Students' Experience in Facing Flood Disasters

Location	Classification		
	Good (%)	Sufficient (%)	Poor (%)
Farther from the river	76	24	0
Near from the river	84	16	0

A comparison between the two locations shows that students in Primary schools near the

river are more likely to have a better experience in facing floods compared to students in schools far from the river. The percentage of 'good' experiences in schools near the river is higher than in those far from the river. Conversely, more students from schools far from the river fall into the 'fair' category compared to those from schools near the river. The absence of any experiences rated as 'poor' in either location indicates that, in general, students' experiences with floods are positive.

Table 2. Percentage of Primary School Students' Preparedness in Facing Flood Disasters

Location	Classification				
	Very Prepared (%)	Prepared (%)	Sufficient (%)	Not Prepared (%)	Very Not Prepared (%)
Farther from the River	38	61	1	0	0
Near from the River	30	70	0	0	0

The analysis results show a variation in the levels of experience, disaster risk reduction awareness, and flood preparedness among Primary school students based on the proximity of the school's location to the river. Students in schools far from the river demonstrate higher levels of preparedness, which can be attributed to a formal learning process that emphasizes theoretical and preventive aspects rather than direct experience. This pattern indicates that real experience does not always align with levels of awareness and preparedness; instead, the two complement each other. Field experience builds emotional and adaptive resilience, while knowledge-based disaster education strengthens preparedness and awareness.

Student disaster preparedness is not merely about mastering technical survival skills; it represents a form of ecological citizenship that connects civic responsibility with environmental awareness. Empirical research on disaster risk reduction education in Primary schools indicates that structured learning programs enhance students' knowledge and response. At the same time participatory training strengthens their risk perception and willingness to engage in preventive behaviors (Morote & Olcina, 2024; Shah et al., 2024). Recent educational research emphasizes that developing disaster preparedness in Primary school students requires an experiential and participatory approach that connects environmental learning with civic responsibility. Galang & Astillero (2025) highlighted the effectiveness of practical, hands-on activities and simulations in enhancing students' preparedness beyond theoretical knowledge, integrating the emotional and psychological aspects of disaster risk reduction. Experiential learning is key to bridging the gap between knowledge and action, effectively translating awareness into sustainable behaviors through direct engagement (Velásquez-Espinoza & Alcántara-Ayala, 2025; Widowati et al., 2025). Preparedness is not only defined as an emergency response capability but also as part of the school's daily activities that support environmental sustainability (Sheehy et al., 2024).

Conclusion

Students near the river possess better empirical experience in dealing with floods, whereas students farther from the river exhibit higher levels of formal preparedness. The study concludes that disaster preparedness should not be viewed merely as a technical survival skill but must be reconceptualized as a form of ecological citizenship. The high level of preparedness among students serves as crucial capital that can be transformed into sustainable ecological participation. Therefore, effective disaster education must integrate experience-based learning with a framework of environmental ethics and collective responsibility.

Acknowledgment

The authors would like to thank the students and teachers of SDN 006, 009, and 010 Loa Janan Ilir, as well as all parties who have contributed to this research.

References

- Aghaei, N., Seyedin, H., & Sanaeinasab, H. (2018). Strategies for disaster risk reduction education: A systematic review. *Journal of Education and Health Promotion*, 7, 98. https://doi.org/10.4103/jehp.jehp_31_18
- Ardiansyah, M., Nugraha, R. A., Iman, L. O. S., & Djatmiko, S. D. (2021). Impact of Land Use and Climate Changes on Flood Inundation Areas in the Lower Cimanuk Watershed, West Java Province. *Jurnal Ilmu Tanah Dan Lingkungan*, 23(2), 53–60. <https://doi.org/10.29244/jitl.23.2.53-60>
- Ariyaningsih, & Shaw, R. (2022). Integration of SETS (Social–Ecological–Technological Systems) Framework and Flood Resilience Cycle for Smart Flood Risk Management. *Smart Cities*, 5(4), 1312–1335. <https://doi.org/10.3390/smartcities5040067>
- Christodoulou, A., & Grace, M. (2025). Becoming ‘Wild Citizens’: Children’s Articulation of Environmental Citizenship in the Context of Biodiversity Loss. *Science & Education*, 34(3), 969–997. <https://doi.org/10.1007/s11191-024-00558-4>
- Činčera, J., Romero-Ariza, M., Zabic, M., Kalaitzidaki, M., & del Consuelo Díez Bedmar, M. (2020). *Environmental Citizenship in Primary Formal Education BT - Conceptualizing Environmental Citizenship for 21st Century Education* (A. C. Hadjichambis, P. Reis, D. Paraskeva-Hadjichambi, J. Činčera, J. Boeve-de Pauw, N. Gericke, & M.-C. Knippels (eds.); pp. 163–177). Springer International Publishing. https://doi.org/10.1007/978-3-030-20249-1_11
- del Castillo, F. A. (2022). Ecological Citizenship and Climate Change: Role of Education in Public Health. *Disaster Medicine and Public Health Preparedness*, 16(6), 2230. <https://doi.org/DOI: 10.1017/dmp.2022.68>
- Fathur. (2020). *Disdik Persilakan Libur saat Sekolah Terendam Banjir*. <https://selasar.co/read/2020/01/14/707/disdik-persilakan-libur-saat-sekolah-terendam-banjir>
- Galang, R. P., & Astillero, J. A. (2025). *Disaster Preparedness Among Primary Learners Towards Risk Reduction*. 7(3), 195–216.
- Kedhaton, A. S. (2024). *Peranan Pengalaman dan Kesadaran Pengurangan Risiko Bencana Terhadap Kesiapsiagaan Siswa dalam Menghadapi Bencana Banjir di Loa Janan Ilir, Kalimantan Timur*. Universitas Negeri Yogyakarta.
- Kedhaton, A. S., & Krismondo, A. (2024). Monitoring Penataan Permukiman Tepian Sungai Mahakam Di Kota Samarinda: Studi Kasus Daerah Sempadan Sungai Kecamatan Loa Janan Ilir, Palaran Dan Samarinda Seberang. *Jurnal Riset Inossa : Media Hasil Riset Pemerintahan, Ekonomi Dan Sumber Daya Alam*, 5(02), 39–51. <https://doi.org/10.54902/jri.v5i02.141>
- Masocha, W., Takaidza, N., Manyani, A., & Mutseekwa, C. (2025). Disaster risk reduction integration into school curriculum: A global analysis. *European Journal of Sustainable Development Research*, 9(1), 1–9. <https://doi.org/10.29333/ejosdr/15820>
- Morote, Á.-F., & Olcina, J. (2024). Preventing through Sustainability Education: Training and the Perception of Floods among School Children. *Sustainability*, 16(11). <https://doi.org/10.3390/su16114678>
- Saraswati, S., Nusantara, E., Mahardika Christian, G. P., Arif Hartanto, M., Prihatin, S., Aida Fitrotur Rahmah, F., Titania Syafika, F., & Rizqiani Khoirunnisa, H. (2024). Program Peningkatan Pengetahuan dan Kesiapsiagaan Bencana Banjir pada Siswa SD NegeriBatusari 6 Kabupaten Demak. *Jurnal Abdidias*, 5(4), 313–318. <https://doi.org/10.31004/abdidias.v5i4.952>
- Septiningrum, U. A. D., Wibowo, Y. A., & Dewi, R. P. (2022). An Analysis of Primary School Vulnerability in Flood-prone Areas, Sukoharjo, Indonesia. *Proceedings of the International Conference of Learning on Advance Education (ICOLAE 2021)*, 662(Icolae 2021), 991–1001. <https://doi.org/10.2991/assehr.k.220503.107>
- Setiawan, H., Jalil, M., Enggi, M., Purwadi, F., Adios, C., Brata, A. W., & Syaful Jufda, A. (2020).

Analysis of the Causes of Flooding in Samarinda City. *Jurnal Geografi Gea*, 20(1), 39–43. <https://ejournal.upi.edu/index.php/gea>

Shah, A. A., Khan, N. A., Ullah, W., Khan, A., Alotaibi, B. A., Ullah, A., & Amri, A. (2024). Disaster risk reduction education (DRRE) in Primary education of Pakistan: Challenges and scaling up endeavours. *International Journal of Disaster Risk Reduction*, 114, 104962. <https://doi.org/https://doi.org/10.1016/j.ijdr.2024.104962>

Sheehy, K., Vackova, P., van Manen, S., Saragih Turnip, S., Rofiah, K., & Twiner, A. (2024). Inclusive disaster risk reduction education for Indonesian children. *International Journal of Inclusive Education*, 28(11), 2529–2545. <https://doi.org/10.1080/13603116.2022.2115156>

Song, L., Li, R. Y. M., & Yao, Q. (2022). An informal institution comparative study of occupational safety knowledge sharing via French and English Tweets: languaculture, weak-strong ties and AI sentiment perspectives. *Safety Science*, 147, 105602. <https://doi.org/https://doi.org/10.1016/j.ssci.2021.105602>

Velásquez-Espinoza, G., & Alcántara-Ayala, I. (2025). Flood risk perception and preparedness in Nicaraguan educational contexts: A study of student perspectives. *International Journal of Disaster Risk Reduction*, 120, 105375. <https://doi.org/https://doi.org/10.1016/j.ijdr.2025.105375>

Widowati, E., Wahyuningsih, A. S., Indrawati, F., & Sulistyani, U. N. L. (2025). School Safety Study: Talking About Disaster Risk Reduction Knowledge in Public and Private Primary Schools, Are They Different? *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, 9(3), 955–968. <https://doi.org/10.22437/jiituj.v9i3.43581>

DEEP LEARNING AND DIGITAL CITIZENSHIP FOR GREEN AND SUSTAINABLE EDUCATION: INSIGHTS FROM INDONESIA

Prince Clinton Immanuel Christian Damanik^{1*} and Arum Sekar Kedhaton²

¹*Department of Primary Teacher Education, Universitas Negeri Jakarta, Jakarta, Indonesia*

²*Department of Geography Education, Universitas Mulawarman, Samarinda, Indonesia*

E-mail: *princedamanik@unj.ac.id

Abstract

Artificial intelligence is transforming civic and environmental learning in schools. This study synthesizes evidence on how deep learning applications enhance digital citizenship to support green and sustainable education in Indonesia and similar developing contexts. Following PRISMA guidelines, 20 peer-reviewed studies from 2015 to 2025 were selected from Scopus, Web of Science, Google Scholar, and Garuda/SINTA. Findings reveal that AI-enabled deep learning fosters participatory digital citizenship through adaptive tools and analytics. Integrating digital platforms with Adiwiyata and civic curricula improves environmental literacy and sustainability-related behaviors aligned with SDGs 13 and 15. Ongoing challenges include limited teacher AI-TPACK readiness, data ethics concerns, and the digital divide. A context-sensitive model embedding deep learning within Pancasila and Adiwiyata frameworks is proposed, with policy and teacher education implications to advance greener, more innovative, and sustainable schools.

Keywords: digital citizenship; sustainable education; deep learning; green education

Introduction

Artificial intelligence (AI) is reshaping civic and environmental education by integrating deep learning into curricula to boost engagement, sustainability awareness, and digital citizenship (Shi et al., 2023; Yim & Su, 2025). AI systems personalize instruction, foster critical thinking, and strengthen environmental literacy (Chalkiadakis et al., 2024; Kumari, 2024). In Indonesia, Adiwiyata and Pancasila-based civic education embed moral–environmental values and provide fertile ground for adaptive, culturally responsive AI use (Kodir et al., 2022; Hajj-Hassan et al., 2024; O’Flaherty & Liddy, 2017). Integrating AI into Pancasila-based civic education can reinforce digital citizenship while preserving cultural identity and environmental ethics, aligning with the SDGs (Yorman & Sadam, 2025; Musa et al., 2024; Aeni et al., 2024; Damanik et al., 2025).

Evidence shows AI-enhanced approaches improve inclusion, digital literacy, and sustainability behaviors when technologies are localized within moral–cultural contexts (Triyani et al., 2021; Hajj-Hassan et al., 2024). Still, adoption faces infrastructure gaps, unequal access, limited teacher readiness, and data-ethics concerns, demanding equity-minded, culturally relevant implementation to avoid digital inequality or algorithmic bias (Aderibigbe et al., 2023; Helmiatin et al., 2024; Tan et al., 2024). Even so, when aligned with Pancasila and Adiwiyata, AI can help democratize quality education and cultivate environmentally conscious, digitally competent

learners who advance a greener future (Makinde et al., 2024; Kioupi & Voulvoulis, 2019), with measurable gains in participation, ethics, stewardship, and community resilience.

Method

This study conducted a PRISMA 2020–based systematic review (Page et al., 2021), searching Scopus, Google Scholar, and SINTA (2015–2025) on deep learning, AI in education, digital citizenship, sustainability, Pancasila, and Adiwiyata. Of 320 records, 80 duplicates were removed; 240 titles/abstracts were screened, 40 full texts reviewed, and 20 studies included. Thematic analysis guided by Garzón et al. (2025) with triangulated coding identified three themes: deep learning enabling participatory digital citizenship, AI advancing environmental literacy, and constraints in teacher readiness, ethics, and infrastructure. Consistent with Matos et al. (2025), the synthesis proposes a context-sensitive framework integrating AI and deep learning into Indonesia’s Adiwiyata and Pancasila-based civic education.

Result and Discussion

Deep Learning as a Catalyst for Digital Citizenship and Civic Responsibility

The reviewed studies indicate that artificial intelligence (AI) and deep learning contribute significantly to civic and environmental education by fostering interactive, reflective, and ethical learning environments (Shi et al., 2023; Yim & Su, 2025; Chalkiadakis et al., 2024). Beyond content delivery, deep learning applications such as adaptive platforms, virtual tutors, and analytics-based assessments provide timely feedback, scaffold metacognition, and personalize challenges that nudge learners toward higher-order reasoning and accountable online behavior (Edwards et al., 2020; Kumari, 2024). These tools encourage students to think critically, collaborate effectively, and act responsibly as digital citizens by linking digital actions with civic consequences, for example, verifying sources, practicing respectful discourse, and documenting community engagement. In the Indonesian context, integrating AI within Pancasila-based civic education strengthens national identity and moral reasoning while positioning technology as a medium for cultivating ethical awareness, empathy, and social responsibility through value-laden scenarios and community projects (Yorman & Sadam, 2025; Musa et al., 2024; Aeni et al., 2024). The accumulating evidence suggests that AI can enhance both digital competence and civic values when guided by the philosophical foundations of Pancasila, especially when assessment rubrics explicitly capture civic dispositions and prosocial participation (Triyani et al., 2021; Damanik et al., 2024).

AI Integration and Environmental Learning through Adiwiyata and Sustainability Frameworks

AI is increasingly influential in sustainability and environmental education, not only as a content area but as a methodological catalyst for inquiry. The integration of AI-based analytics, environmental modeling, and gamified learning supports improvements in students’ ecological understanding, systems thinking, and sustainability-oriented behaviors (Hajj-Hassan et al., 2024; Kumari, 2024; Lo, 2024). Within the Adiwiyata Green School framework, these technologies assist students in analyzing environmental data, forecasting ecological outcomes, and developing collaborative solutions to local issues such as waste management, air quality, and urban greening (Kodir et al., 2022; Suprpto et al., 2023; Junaidah et al., 2025). Classroom tasks can connect dashboards and sensors to civic action turning findings into school policies or neighborhood initiatives, so that data literacy translates into stewardship. Linking AI-supported environmental instruction with civic and moral education enhances digital ethics and ecological responsibility, aligning with Indonesia’s national values and the Sustainable Development Goals, while also

cultivating reflective practices like impact journaling and peer accountability (O’Flaherty & Liddy, 2017; Lozano-Díaz & Fernández-Prados, 2020).

Implementation Challenges: Infrastructure, Teacher Readiness, and Ethics

While the potential of AI in education is evident, several challenges persist, particularly in developing contexts where capacity and policy frameworks vary (Aderibigbe et al., 2023; Helmiatin et al., 2024). Teachers often demonstrate limited AI-TPACK readiness, and many schools face infrastructure gaps, device scarcity, and unequal digital access that exacerbate achievement divides (Aeni et al., 2024; Tan et al., 2024). Ethical concerns related to data privacy, algorithmic bias, model transparency, and regulatory oversight remain unresolved, especially when third-party platforms process sensitive student data (Farooqi et al., 2024). Addressing these issues requires targeted professional development, co-design with teachers, and curriculum adaptation that integrates AI tools within culturally rooted pedagogical frameworks and clear governance protocols (Almasri, 2024; Makinde et al., 2024). Sustainable implementation must balance technological advancement with ethical awareness and contextual relevance, including low-tech alternatives, accessibility accommodations, and continuous impact evaluation to avoid unintended harms (Hajj-Hassan et al., 2024).

A Context-Sensitive Framework for Greener and Smarter Schools

While the potential of AI in education is evident, several stubborn constraints persist, especially in developing contexts where capacity, policy coherence, and funding stability vary widely (Aderibigbe et al., 2023; Helmiatin et al., 2024). Teachers frequently exhibit limited AI-TPACK readiness, and many schools confront infrastructure gaps, device scarcity, intermittent connectivity, and unequal digital access that deepen existing achievement divides and constrain pedagogical experimentation (Aeni et al., 2024; Tan et al., 2024). Ethical tensions around data privacy, algorithmic bias, model transparency, and weak regulatory oversight remain unresolved, particularly when third-party platforms process sensitive student data across opaque data pipelines (Farooqi et al., 2024). Addressing these issues requires targeted professional development, closer co-design with teachers to safeguard agency, and curriculum adaptation that embeds AI tools within culturally rooted pedagogies, local language needs, and clearly articulated governance protocols (Almasri, 2024; Makinde et al., 2024). Sustainable implementation also hinges on practicalities often overlooked: total cost of ownership, maintenance and support, vendor lock-in risks, accessibility accommodations, and iterative monitoring and impact evaluation to surface unintended harms and equity trade-offs over time (Hajj-Hassan et al., 2024).

Conclusion

Integrating artificial intelligence and deep learning into civic and environmental education can accelerate sustainable, green schooling. Grounded in Pancasila and Adiwiyata, effective implementation through teacher readiness, equitable infrastructure, and strong data governance enhances digital citizenship, environmental literacy, and ethical awareness, cultivating digitally capable, socially responsible, ecologically conscious learners and aligning policy, pedagogy, and measurable sustainability outcomes.

Acknowledgment

The author would like to thank all parties who have contributed to this research.

References

Aderibigbe, J. O., Ohenhen, R. C., Nwaobia, I. A., Gidiagba, E., & Ani, O. (2023). Artificial intelligence in developing countries: Bridging the gap between potential and implementation.

- Computer Science and Information Technology Research Journal, 4(3), 234–251. <https://doi.org/10.51594/csitrj.v4i3.629>
- Aeni, K., Andrijati, N., Astuti, T., Rosianingrum, A., & Afkawati, S. H. (2024). Strengthening Pancasila Student Profile Based on Technological Pedagogical and Content Knowledge. *JTP - Jurnal Teknologi Pendidikan*, 26(3), 1171–1180. <https://doi.org/10.21009/jtp.v26i3.50339>
- Almasri, F. (2024). Exploring the Impact of Artificial Intelligence in Teaching and Learning of Science: A Systematic Review of Empirical Research. *Research in Science Education*, 54, 977–997. <https://doi.org/10.1007/s11165-024-10176-3>
- Chalkiadakis, A., Seremetaki, A., Kanellou, A., Kallishi, M., Morfopoulou, A., Moraitaki, M., & Mastrokourou, S. (2024). Impact of artificial intelligence and virtual reality on educational inclusion: A systematic review of technologies supporting students with disabilities. *Education Sciences*, 14(11), 1223. <https://doi.org/10.3390/educsci14111223>
- Damanik, P. C. I. C., Husaeni, R. A., Jayanti, F. D., Uli, A. A., & Chaled, M. I. (2025). Integrating digital citizenship in primary schools to advance sustainable development goals in Indonesia. *JIMU: Jurnal Ilmiah Multidisipliner*, 3(4). <https://doi.org/10.70294/jimu.v3i04.1302>
- Damanik, P. C. I. C., Murdiono, M., & Suharno. (2024). Enhancing university students' interest in learning and creativity through a project-based learning model with Instagram Reels media. *International Journal of Multidisciplinary Research and Analysis*, 7(8), 3809–3815. <https://doi.org/10.47191/ijmra/v7-i08-21>
- Edwards, D. B., Jr., Sustarsic, M., Chiba, M., McCormick, M., Goo, M., & Perriton, S. (2020). Achieving and Monitoring Education for Sustainable Development and Global Citizenship: A Systematic Review of the Literature. *Sustainability*, 12(4), 1383. <https://doi.org/10.3390/su12041383>
- Farooqi, M. T. K., Amanat, I., & Awan, S. M. (2024). Ethical considerations and challenges in the integration of artificial intelligence in education: A systematic review. *Journal of Excellence in Management Sciences*, 3(4), 35–50. <https://doi.org/10.69565/jems.v3i4.314>
- Garzón, J., et al. (2025). Systematic review of artificial intelligence in education: trends, gaps, and methodological insights. *Multimodal Technologies and Interaction*, 9(8), 84. <https://doi.org/10.3390/mti9080084>
- Hajj-Hassan, H. H., Makki, S. M. K., & Dbaibo, A. J. (2024). Environmental education: A systematic review on the use of digital tools for fostering sustainability awareness. *Sustainability*, 16(9), 3733. <https://doi.org/10.3390/su16093733>
- Helmiatin, Hidayat, A., & Kahar, M. R. (2024). Investigating the adoption of AI in higher education: a study of public universities in Indonesia. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2380175>
- Junaidah, Nikita Aeni Mahardika, & Ma'arif, M. A. (2025). Promoting Green Madrasa as Environmental Education Program: How to Implement and Maintain It. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, 6(1), 39–54. <https://doi.org/10.31538/munaddhomah.v6i1.1572>
- Kioui, V., & Voulvoulis, N. (2019). Education for Sustainable Development: A Systemic Framework for Connecting the SDGs to Educational Outcomes. *Sustainability*, 11(21), 6104. <https://doi.org/10.3390/su11216104>
- Kodir, A., Syaifulloh, M., Monassa, I. I., Sumarmi, S., & Zubaidah, S. (2022). Environmental education at Adiwiyata schools and the conservation of the Brantas watershed in Indonesia. *KnE Social Sciences*, 7(16), 301–306. <https://doi.org/10.18502/kss.v7i16.12175>
- Kumari, R. K. (2024). Transforming education. *Advances in Educational Technologies and Instructional Design*, 22–42. <https://doi.org/10.4018/979-8-3693-2256-7.ch002>
- Lo, N. P.-K. (2024). The confluence of digital literacy and eco-consciousness: Harmonizing digital skills with sustainable practices in education. *Platforms*, 2(1), 15–32. <https://doi.org/10.3390/platforms2010002>

- Lozano-Díaz, A., & Fernández-Prados, J. S. (2020). Educating digital citizens: An opportunity for a critical and activist perspective of sustainable development goals. *Sustainability*, 12(18), 7260. <https://doi.org/10.3390/su12187260>
- Makinde, S. O., Sulyman, B. M., & Ibrahim, A. (2024). Beyond borders: Leveraging technology to achieve sustainable development goals in education. *International Journal of Universal Education*, 2(2), 90–100. <https://doi.org/10.33084/ijue.v2i2.8586>
- Matos, T., et al. (2025). A systematic review of artificial intelligence applications in education. *Heliyon*, 11(2), e34017. <https://doi.org/10.1016/j.heliyon.2025.e34017>
- Musa, M., & Wulan, B. A. C. (2024). Building smart and good citizens in the digital era through citizenship education in Indonesia. *International Journal of Social Research*, 2(1), 34–48. <https://doi.org/10.62894/4b6bmz42>
- O’Flaherty, J., & Liddy, M. (2017). The impact of development education and education for sustainable development interventions: A synthesis of the research. *Environmental Education Research*, 24(7), 1031–1049. <https://doi.org/10.1080/13504622.2017.1392484>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., et al. (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews*. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Shi, G., Chan, K. K., & Lin, X. F. (2023). A systematic review of digital citizenship empirical studies for practitioners. *Education and Information Technologies*, 28, 3953–3975. <https://doi.org/10.1007/s10639-022-11383-z>
- Suprpto, A. S., & Hartini, T. I. (2023). Evaluation of the implementation of the Adiwiyata program in elementary schools in Grogol Petamburan District, Jakarta, Indonesia. *Community Medicine and Education Journal*, 4(2), 286–292. <https://doi.org/10.37275/cmej.v4i2.312>
- Tan, L., Wong, S., & Chen, M. (2024). Assessing AI adoption in developing country academia: A trust- and privacy-augmented UTAUT framework. *PLOS ONE*, 19(9), e0309876. <https://doi.org/10.1371/journal.pone.0309876>
- Triyani, T., Mustika, M., Sakman, S., & Mantir, H. (2021). Development of high order thinking skills-based assessment tools in Pancasila course: Critical digital citizenship oriented. *Journal Lingua Idea*, 12(2), 136–144. <https://doi.org/10.20884/1.jli.2021.12.2.4942>
- Yim, I. H. Y., & Su, J. (2025). Artificial intelligence (AI) learning tools in K–12 education: A scoping review. *Journal of Computers in Education*, 12, 93–131. <https://doi.org/10.1007/s40692-023-00304-9>
- Yorman, Y., & Sadam, S. (2025). Pancasila as an ethics of social media to realize digital citizens. *Journal of Social Studies Education*, 1(1), 37–46. <https://doi.org/10.71094/josse.v1i1.89>

Scope : Education

Article ID : 306

DIGITAL TRANSFORMATION OF ISLAMIC RELIGIOUS EDUCATION: SHAPING “SMART PEOPLE” BASED ON ECOTHEOLOGY TOWARD A SMART AND SUSTAINABLE CITY

Zulfatun Ni'mah

Faculty of Social Sciences and Law, State University of Jakarta, Jakarta, Indonesia

E-mail: zulfatun.nimah@unj.ac.id

Abstract

Rapid urbanization has created ecological pressures that demand a city development approach grounded in moral and spiritual values. This study aims to analyze the integration of Islamic ecotheology into the digital transformation of Islamic Religious Education (IRE) as a means to develop “Smart People” for building smart and sustainable cities. The research employed a qualitative-descriptive method through literature review, digital content analysis, and case studies at Istiqlal Mosque and Nurul Hakim Islamic Boarding School. The findings reveal that the values of *khilafah* (stewardship), *mizan* (balance), and *israf* (moderation) are relevant to the principles of Smart Green City and Sustainable Development Goals (SDGs) indicators. The digital transformation of IRE enhances the internalization of ecological values through interactive learning and data-driven technology. The study concludes that integrating ecotheology into digital education fosters eco-spiritual intelligence and proposes a Three-Pillar Model of Digital Ecotheological IRE as a new conceptual framework for equitable and sustainable urban development.

Keywords: Islamic Religious Education, Ecotheology, Digital Transformation, Smart People, Smart City

Introduction

Uncontrolled urbanization has placed great pressure on natural resources and social well-being, making sustainability a crucial concern for cities (Hafez, 2020; Kriswandanu et al., 2023). The Smart City concept, emphasizing efficiency through technology, often overlooks ethical and humanistic aspects (Kitchin, 2016). The current ecological crisis is not solely a technical or regulatory problem but a moral and philosophical one (Amirullah, 2015). Without moral grounding, smart city development risks producing new inequalities and unsustainable outcomes (Chen, 2025).

Islamic Religious Education (IRE) plays a vital role in shaping moral awareness and ecological responsibility. Islamic ecotheology emphasizes humankind's role as *khalifah* (steward) who maintains *mizan* (cosmic balance) and avoids *israf* (wastefulness) (Al-Jayyousi, 2016; Fitriansyah, 2024; Nugroho et al., 2025). These values align with sustainability principles and the SDGs, particularly SDG 11 (Sustainable Cities) and SDG 12 (Responsible Consumption).

The Fourth Industrial Revolution opens new opportunities for the digital transformation of IRE, expanding access to ecological education through online platforms, apps, and gamified learning (Rahayu et al., 2025; Ihsan, 2025; Manshur & Isroani, 2023). However, digitalization must be ethically guided to prevent superficial religiosity and digital inequality. This study

therefore investigates how Islamic ecotheology can strengthen digital IRE as an instrument for developing Smart People citizens who are intellectually, spiritually, and ecologically literate.

Method

This research employed a qualitative-descriptive design using library research, digital content analysis, and comparative case studies. Data were gathered from academic literature, online learning platforms, and institutional reports between September and October 2025. The case studies at Istiqlal Mosque and Nurul Hakim Islamic Boarding School were examples of eco-mosque and eco-pesantren practices integrating theological ethics with digital innovation. Thematic analysis was applied to synthesize findings into a conceptual model linking IRE, ecotheology, and innovative urban development.

Result and Discussion

This study employed three complementary methods: a systematic literature review (SLR), digital content analysis, and a comparative case study. The SLR identified key Islamic ecotheological principles, *khilafah* (stewardship), *mizan* (balance), and *israf* (moderation) as ethical foundations for sustainability (Al-Jayyousi, 2016; Fitryansyah, 2024; Rakhmat, 2022). Digital content analysis explored how these values appear in Islamic Religious Education (IRE) and online *da'wah* materials, while the comparative study at the Istiqlal Eco-Mosque (Jakarta) and Nurul Hakim Eco-Pesantren (Lombok) examined their concrete implementation. Table 1 summarizes the integration of findings from these three methods.

Tabel 1. Integration of finding

Main Theme	Evidence from Literature Review (SLR)	Findings from Digital Content Analysis	Validation from Case Studies (Comparative Study)
Ecotheology in Islamic Religious Education (IRE) & SDGs	The literature emphasizes the principles of <i>khilafah</i> (stewardship), <i>mizan</i> (balance), and <i>israf</i> (avoidance of excess) as ethical foundations for sustainability (Al-Jayyousi, 2016; Fitryansyah, 2024b; Rakhmat, 2022).	E-learning content in IRE and online <i>da'wah</i> often connects Qur'anic teachings with environmental issues, although not yet in a systematic manner.	Istiqlal Mosque applies environmentally friendly technologies, while Nurul Hakim integrates the <i>wasathiyah</i> (moderation) curriculum with daily ecological practices.

Digital Transformation of IRE → Eco-Spiritual Intelligence	Global literature highlights the potential of digital education to expand ecological literacy (Guandalini, 2022; Ninsiana et al., 2024; UNESCO, 2018). This approach emphasizes the formation of eco-spiritual intelligence as a synergy between digital literacy and ecological awareness.	Analysis of digital IRE platforms Reveals anti- <i>israf</i> narratives and messages promoting resource efficiency.	Istiqlal uses smart meters for energy transparency, while Nurul Hakim utilizes social media for students' environmental campaigns.
The Role of Islamic Institutions in Smart Cities	Studies identify religious institutions as agents of social transformation and public ethics in sustainable development (Schliesser, 2023, 2024).	Digital content from mosques and pesantrens increasingly promotes a “green lifestyle” grounded in religious principles.	Istiqlal serves as an eco-mosque pioneering green technology, while Nurul Hakim acts as an eco-pesantren fostering eco-ethical Smart People.

Ecotheology and Its Relevance to Urban Sustainability

Islamic ecotheology provides a holistic ethical framework that integrates spirituality with environmental responsibility. The concepts of *khilafah* (stewardship), *mizan* (balance), and *israf* (moderation) promote harmony between humans and nature, aligning with SDGs 11, 12, and 13 (Rakhmat, 2022; Fitryansyah, 2024; Nugroho et al., 2025). Literature findings show that Islamic ethics can serve as a moral corrective to the technocentric bias of Smart City frameworks—shifting the notion of “smartness” from mere technological efficiency to moral intelligence that upholds ecological sustainability.

Digital Transformation and Eco-Spiritual Intelligence

Digital IRE offers a transformative model for developing eco-spiritual intelligence that integrates environmental ethics, digital literacy, and religious awareness (Guandalini, 2022; Ninsiana et al., 2024). Unlike conventional IRE, which depends on teachers’ moral exemplars, digital IRE enables experiential learning through visualization, simulation, and gamification. For example, e-learning platforms that link Qur’anic teachings on *israf* (moderation) with real-time environmental data make moral reflection tangible and applicable. Additionally, digital IRE promotes multi-directional engagement, where learners act as recipients and content creators who spread ecological values through social media, fostering collective eco-consciousness and a culture of green *da’wah*.

Case Studies: Eco-Mosque and Eco-Pesantren

The case studies reveal two complementary models of ecotheological practice. The Istiqlal Eco-Mosque exemplifies a top-down, technology-oriented approach, where energy-efficient

infrastructure and digital monitoring significantly reduce resource consumption, showcasing how governance and innovation can align with Islamic sustainability ethics (Darmawan et al., 2024; IFC, 2022; Hidayat et al., 2018; EDGE Buildings, 2022) Its *wakaf energi* initiative further demonstrates the role of Islamic finance in supporting institutional climate action.

Conversely, the Nurul Hakim Eco-Pesantren represents a bottom-up, community-driven model emphasizing behavioral change. Through a hidden curriculum grounded in *wasathiyah* (moderation) and *amanah* (responsibility), students engage in waste segregation, reforestation, and digital environmental campaigns (Aulia et al., 2017; Herdiansyah et al., 2018; Murdianto, 2022). This model underscores that ecological ethics begin with individual and communal habits before influencing wider urban systems. Both cases show that when Islamic education integrates ecological and digital dimensions, it fosters “Smart People” who harmonize faith, intellect, and sustainability in daily life.

The Three-Pillar Model of Digital Ecotheological IRE

The synthesis yields a Three-Pillar Model:

1. Ethical Integration: embedding *khilafah*, *mizan*, *israf* as moral bases for sustainability;
2. Digital Transformation: leveraging technology for real-time learning and collaboration;
3. Practical Implementation: institutionalizing eco-ethics through community projects and green governance.

This model positions IRE as an active contributor to ecological civilization. By merging digital innovation with theological ethics, Islamic education shapes eco-literate citizens who uphold ‘*adl* (justice) and *mizan* (balance) in the digital era.

Conclusion

This study finds that integrating Islamic ecotheology into Islamic Religious Education (IRE) creates a meaningful connection between spiritual values, digital innovation, and urban sustainability through the formation of eco-spiritual intelligence. The proposed Three-Pillar Model offers a fresh conceptual framework to apply the principles of *khilafah*, *mizan*, and *israf* within the Smart City context. It is suggested that future studies examine this model over time and across diverse educational and religious institutions in various regions.

Acknowledgment

The author would like to thank all parties who have contributed to this research.

References

- Al-Jayyousi, O. R. (2016). *Islam and Sustainable Development: New Worldviews*. Gower. <https://doi.org/10.4324/9781315589947>
- Amirullah. (2015). Krisis Ekologi: Problematika Sains Modern. *Lentera*, XVIII,(1). https://journal.uinsi.ac.id/index.php/lentera_journal/article/view/425
- Aulia, R. N., Isnaini, D. E. N., & Khumairoh, U. (2017). Pengelolaan Lingkungan Berbasis Pesantren (Studi Kasus di Pondok Pesantren Nurul Hakim Lombok). *Hayula: Indonesian Journal of Multidisciplinary Islamic Studies*, 1(2), 229–244. <https://doi.org/10.21009/hayula.001.2.06>
- Chen, L. (2025). Smart Cities and Social Equity: A Review of Digital Urban Governance in Southeast Asia. *International Journal of Social Science and Applied Technology*, 1(1), 1–11. <https://doi.org/10.64391/ijssat.v1i1.001>
- Darmawan, A. Z., Sofiyah, E. S., & Qonitan, F. D. (2024, July 3). *Analysis of Carbon Footprint and Impact of Global Warming Potential on Aspects of Transportation, Electricity and Water Use in Istiqlal Mosque*. Proceedings of the 2nd International Conference on Nature-Based Solution in Climate Change, RESILIENCE 2023, 24 November 2023, Jakarta, Indonesia. <https://eudl.eu/doi/10.4108/eai.24-11-2023.2347559>

- EDGE Buildings. (2022). *Masjid Istiqlal*. <https://edgebuildings.com/project-studies/masjid-istiqlal/>
- Fitriansyah, M. A. (2024). Islamic Perspective on Urban Ecology Environmental Preservation in The Context of Urbanization. *Al-Madinah: Journal of Islamic Civilization*, 1(2), 145–156. <https://doi.org/10.70901/2qf36d84>
- Hafez, R. M. H. (2020). Cities Under Pressure Case Study Of Nasr City District - Cairo. *JES. Journal of Engineering Sciences*, 48(4), 613–632. <https://doi.org/10.21608/jesaun.2020.110506>
- Hatem, F. ostafa. (2023). Making Cities Smarter for an Inclusive Green Transition Towards a Long-term Sustainable Development: A Critical Literature Review -. *IET The Institute of Engineering and Technology*, 5(4), 243–253.
- Herdiansyah, H., Sukmana, H., & Lestarini, R. (2018). Eco-Pesantren as A Basic Forming of Environmental Moral and Theology. *Kalam*, 12(2), 303–326. <https://doi.org/10.24042/klm.v12i2.2834>
- Hidayat, E. R., Danuri, H., & Purwanto, Y. (2018). Ecomasjid: The First Milestone Of Sustainable Mosque In Indonesia. *Journal of Islamic Architecture*, 5(1), 20–26. <https://doi.org/10.18860/jia.v5i1.4709>
- IFC (International Finance Corporation). (2022). *Masjid Nasional Indonesia Menjadi Ramah Lingkungan dalam Kolaborasi Pertama di Dunia dengan Program EDGE IFC* [Text/HTML]. IFC. <https://www.ifc.org/in/pressroom/2022/26920>
- Ihsan, I. (2025). Transformasi Pendidikan Agama Islam Di Era Digital: Peluang Dan Tantangan Dalam Membentuk Generasi Islami. *Ensiklopedia Research and Community Service Review*, 4(2), 247–256. <https://doi.org/10.33559/err.v4i2.2949>
- Kitchin, R. (2016). The ethics of smart cities and urban science. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences*, 374(2083), 20160115. <https://doi.org/10.1098/rsta.2016.0115>
- Kriswandanu, A. R., Muhtadi, M. A., Suprayitno, E., Ahmaniyah, A., & Wardita, Y. (2023). Effects of Urbanization, Transport Infrastructure, Air Quality, and Health Outcomes on the Quality of Life of Jakarta City Population. *Jurnal Geosains West Science*, 1(02), 54–63. <https://doi.org/10.58812/jgws.v1i02.393>
- Manshur, A., & Isroani, F. (2023). Tantangan Kurikulum Pendidikan Agama Islam di Era Digital. *Edukasi Islami: Jurnal Pendidikan Islam*, 12(04). <https://doi.org/10.30868/ei.v12i04.8114>
- Murdianto, M. (2022). The Implementation of environmental Education at pondok pesantren Nurul Hakim Kediri, West Lombok. *EDUMASPUL: JURNAL PENDIDIKAN*, 6(2), 1410–1422.
- Nugroho, M. A., Billah, A., Rahmah, Y. A., & Trisnadariawati, L. P. (2025). Green Wasathiyyah Campus as a Space for Transforming Islamic Wasathiyyah Values through Ecotheology. *Analisa: Journal of Social Science and Religion*, 10(1), 79–100. <https://doi.org/10.18784/analisa.v10i1.3206>
- Rahayu, S., Nabila, K., Ulandari, E. F., & Mukmin, M. (2025). Model Strategi Pembelajaran PAI Era Revolusi Industri 4.0 dan Society 5.0. *Journal of Instructional and Development Researches*, 5(1), 97–105. <https://doi.org/10.53621/jider.v5i1.491>
- Rakhmat, A. (2022). Islamic Ecotheology: Understanding The Concept Of Khalifah And The Ethical Responsibility of The Environment. *Academic Journal of Islamic Principles and Philosophy*, 3(1), 1–24. <https://doi.org/10.22515/ajipp.v3i1.5104>

BUILDING STRONG CITIES THROUGH GREEN EDUCATION AND GOOD EDUCATIONAL MANAGEMENT

Sarah Muthmainnah

State University of Jakarta, East Jakarta, DKI Jakarta, Indonesia

E-mail: sarah.muthmainnah@mhs.unj.ac.id

Abstract

City communities face big challenges because of fast urbanization, globalization, and limited access to good education. This article discusses how proper educational management can be combined with green education to build strong and sustainable cities. The method used is a literature review and descriptive analysis, focusing on the connection between green education practices and educational governance. The discussion shows that using renewable learning resources, developing sustainable curricula, creating eco-friendly school facilities, and applying circular learning systems can make cities stronger by reducing social and educational gaps while improving social and economic welfare. In addition, the cooperation between community participation, green technology in education, and effective school management is an important key to achieving long-term sustainable urban resilience. Therefore, the integration of educational management and green education not only supports sustainable knowledge but also helps city communities face global challenges full of uncertainty.

Keywords: educational management, green education, urban resilience, sustainable development

Introduction

Rapid urbanization has created both opportunities and challenges for education in modern cities. Although urban areas often provide access to advanced technologies and diverse learning environments, they also face serious problems such as environmental degradation, social inequality, and a lack of access to green spaces. Education plays a crucial role in addressing these issues by shaping students' awareness, critical thinking, and sense of environmental responsibility.

Green education is an educational approach that incorporates environmental awareness, sustainability, and responsible living into the learning process. It prepares young generations to become agents of change who contribute to building sustainable cities. At the same time, educational management is essential in ensuring that schools are effectively organized, resources are allocated efficiently, and sustainability policies are successfully implemented.

This study aims to analyze how educational management and green education can work together to build resilient and sustainable cities. The analysis emphasizes the importance of aligning school policies, curricula, and infrastructure with the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 11 (Sustainable Cities and Communities).

Method

This study applies a qualitative literature review approach. Data were collected from academic journals, books, and credible online sources published between 2015 and 2025 that focus on green education, sustainable urban planning, and educational management. The research procedure consisted of three stages:

1. Data Collection: Gathering relevant journal articles from *Sustainability*, *Environmental Education Research*, *Journal of Cleaner Production*, and other peer-reviewed sources.
2. Data Analysis: Reviewing and synthesizing the relationship between educational policies, green school initiatives, and urban resilience.
3. Interpretation: Drawing insights from theories and empirical studies to build a comprehensive understanding of the role of education in sustainable city development.

This method allows for a broad understanding of how educational institutions can contribute to creating environmentally responsible and socially resilient urban communities. This study refers to previous research by Sahlberg (2012) and Schunk (2012) that emphasizes how education management can change learning environments and student behavior.

Result and Discussion

The results of this study reveal that green education plays a significant role in promoting sustainability within cities. Integrating green values into educational systems encourages students and teachers to become more environmentally aware and active in their communities. Many urban schools have started to implement sustainability programs such as waste reduction, renewable energy use, and urban gardening. According to Zhang and Yang (2021), schools that apply environmental learning projects tend to achieve higher student engagement and greater community participation. These initiatives not only teach responsibility toward nature but also strengthen collaboration between schools, local authorities, and community organizations. Educational management is equally important in ensuring that sustainability becomes part of a school's culture. Leadership, planning, and resource management determine whether green education can be applied effectively. Research by Lee et al. (2022) shows that principals who promote sustainability-focused leadership can motivate teachers to apply eco-friendly teaching methods and better resource management practices. Schools that allocate their budgets to renewable energy, efficient facilities, and green spaces tend to provide healthier learning environments that positively affect students' academic performance and well-being.

Urban resilience also depends on collaboration between schools and communities. As noted by Al-Subaie, A., and Evans (2023), partnerships among schools, NGOs, and local communities help strengthen environmental initiatives. In several cities, such as Jakarta, schools collaborate with environmental organizations to conduct tree planting, recycling programs, and urban farming projects. These activities promote social awareness among students while helping to address real urban issues like pollution and waste management. This cooperation demonstrates that education can serve as a bridge between environmental awareness and collective social action.

Technology and innovation further support the growth of green education in urban settings. The use of digital learning platforms reduces paper use, while online collaboration tools enable students to join sustainability projects that reach beyond their schools. Chou and Huang (2020) found that integrating digital green learning can lower carbon emissions in education systems by up to 25%. Smart school management systems also help track energy consumption, waste, and water usage, providing useful data for improving sustainability practices. As cities continue to modernize, the use of technology in education offers an opportunity to make learning both innovative and environmentally friendly.

Despite its positive impact, the implementation of green education still faces several challenges. Some schools lack sufficient funding, trained teachers, and clear policy support from local authorities. Additionally, many schools still prioritize academic achievement and examination results over sustainability-oriented values. Brown et al. (2019) argue that green education should not remain an extracurricular activity but should become an integral part of the curriculum. For this reason, educational managers must develop evaluation systems that measure students' environmental awareness and sustainable behavior alongside their academic achievement. Without such changes, green education will remain a limited initiative rather than a

transformative movement.

Combining educational management with green education is an effective way to build sustainable and resilient cities. Schools can act not only as centers of learning but also as centers of community empowerment. According to UNESCO (2023), sustainable learning cities are characterized by collaboration among governments, schools, and communities that promote continuous learning for all citizens. By embedding environmental awareness and sustainability values into education, cities can develop citizens who are innovative, socially responsible, and ready to contribute to long-term sustainable development.

Conclusion

This study concludes that integrating green education with effective educational management is a key strategy for developing sustainable and resilient cities. Green education empowers students and communities to act responsibly toward the environment, while educational management ensures that sustainability becomes a long-term institutional commitment. When schools, local governments, and communities work together, education becomes a strong driver of social change and urban development. Future research is encouraged to focus on measuring the long-term impact of green education policies on urban growth and the overall quality of life of city residents.

Acknowledgment

The authors would like to express their deepest gratitude to Allah Ta'ala, who has granted strength and guidance to complete this published paper. Special thanks are also extended to the lecturers of the Faculty of Social Sciences and Law, particularly Prof. Dr. Nadiroh, M.Pd, who provided valuable information about the International Conference ICE3SHT 2025. The authors would also like to express sincere appreciation to all friends, especially Vytha, Fiah, Jibrin, Muthia, Mutiara, and many other kind friends who have continuously supported, encouraged, and inspired her throughout this journey. Lastly, deepest gratitude is conveyed to her beloved family, who have continuously provided motivation, guidance, and encouragement throughout the research and writing process.

References

- Akinsemolu, A. A. (2025). *The role of green education in achieving sustainable development outcomes: Review and perspectives*. Renewable and Sustainable Energy Reviews.
- Al-Subaie, A., & Evans, N. (2023). *Sustainability education and community participation in urban contexts*. *Sustainability*, 15(4), 2211–2224.
- Bianchi, R., & López, S. (2023). *The integration of green education in public school systems: Policies and practices*. *International Journal of Educational Development*, 97, 102743.
- Biancardi, A., & Rossi, L. (2024). *Strategies for sustainable learning environments in higher education*. *Environmental Education Research*, 30(2), 177–195.
- Brown, P., Richards, D., & Smith, J. (2019). *Embedding sustainability in school curricula*. *Journal of Environmental Education*, 50(2), 112–126.
- Chou, P. N., & Huang, Y. C. (2020). *Green e-learning for sustainable development in urban schools*. *Computers & Education*, 151, 103872.
- Dupuis, J. (2024). *K–12 science achievement: Time-varying influence of green school programs*. *Journal of Environmental Education*.
- Fauzi, A., & Rahman, M. (2022). *Green school implementation in developing countries: A case from Indonesia*. *Journal of Cleaner Production*, 355, 131781.
- Figueiró, P. S., & Raufflet, E. (2015). *Sustainability in higher education: Systematic review and a methodological framework*. *Journal of Cleaner Production*, 106, 45–58.

- Gómez, M. A., & Fernández, C. (2021). *Green education and innovation in urban schools: A European comparative study*. Sustainability, 13(19), 10824.
- Han, H., & Lee, M. (2020). *Understanding students' eco-friendly behavior through green campus initiatives*. International Journal of Sustainability in Higher Education, 21(3), 509–527.
- Husin, A., Helmi, H., & Nengsih, Y. K. (2025). *Environmental education in schools: Sustainability and hope*. Discover Sustainability, 6(41).
- Jiménez, R. B., García, J., & Torres, M. (2023). *School greenness and academic performance: A multi-city analysis*. International Journal of Environmental Research and Public Health, 20(3), 1456.
- Lee, J., Park, S., & Kim, H. (2022). *Sustainability leadership and school management performance*. Educational Management Administration & Leadership, 50(6), 879–894.
- Li, W., & Zhang, Y. (2020). Environmental awareness in urban education: A systematic review. Environmental Education Research, 26(7), 1023–1039.
- Lim, C. K., & Tan, S. (2022). Mapping global trends in education for sustainable development research. Sustainability, 14(12), 7423.
- Liu, Y., & Wang, L. (2023). The effect of sustainable management practices on environmental literacy among teachers. Teaching and Teacher Education, 123, 103936.
- Martínez, L., & Torres, M. (2021). Urban education and sustainability: Building resilient cities through schools. Journal of Urban Studies, 58(3), 487–505.
- Morales, I., Segalás, J., & Maseck, T. (2024). Evaluation of urban living labs in higher education institutions toward education for sustainable development. Frontiers in Education, 9, 1412380.
- Pauw, J. B.-d., Gericke, N., Olsson, D., & Berglund, T. (2015). The effectiveness of education for sustainable development. Sustainability, 7(11), 15693–15717.
- Redman, A., & Wiek, A. (2021). *Competencies for advancing transformations towards sustainability*. Frontiers in Education, 6, 642276.
- Rogers, L., & Schmidt, E. (2023). *Integrating sustainability in teacher education: A review of pedagogical approaches*. Environmental Education Research, 29(5), 735–750.
- Servant-Miklos, V. (2022). *Environmental education and socio-ecological resilience in urban learners: Case evidence*. Environmental Education Research, 28(9), 1357–1374.
- UNESCO. (2023). Learning cities and sustainable development. Paris: UNESCO Publishing.
- Vargas-Merino, J. A. (2024). *Critical implications of education for sustainable development: Theoretical gaps and implementation challenges*. Journal of Education for Sustainable Development, 18(2), 99–118.
- van den Bogerd, N., Unsworth, R., & Green, A. (2025). *The use of green schoolyards for education*. Environmental Education Research.
- Wals, A. E. J., & Kieft, G. (2020). *Education for sustainability transitions: Research and innovation challenges*. Environmental Education Research, 26(7), 1023–1044.
- Wu, S., & Chang, T. (2023). Digital transformation of green learning environments for sustainable education. Computers & Education, 195, 104719.
- Zhang, L., & Yang, Q. (2021). The impact of green learning environments on student behavior. International Journal of Environmental Research and Public Health, 18(9), 4693.
- Zhao, X., & Chen, J. (2024). Sustainable development competencies through experiential learning in urban schools. Sustainability, 16(1), 334.

PREPARING NEXT-GENERATION EDUCATIONAL LEADERS FOR ENVIRONMENTAL SUSTAINABILITY: LEADERSHIP TRENDS IN THE ERA OF CLIMATE-CONSCIOUS GENERATIONS

Lina^{1*} and Rheza Pratama²

¹*Educational Management, State University of Jakarta, Jakarta, Indonesia*

²*Management, Khairun University, Ternate, Indonesia*

E-mail: *fransiskalina@unj.ac.id

Abstract

In the next decade, Indonesian education management will be dominated by Generations Y, Z, and Alpha, known as the climate-conscious generation. This generational shift demands a transformation in educational leadership to integrate environmental sustainability values. This study analyses how new-generation leadership trends can prepare education leaders to integrate ecological sustainability into educational management. This narrative literature study offers a critical analysis of the preparation of new-generation education leadership in the context of environmental sustainability. The findings show that issues of ecological sustainability, environmentally friendly technology, and sustainability-oriented lifelong learning shape the leadership character of climate-conscious generations. Leadership trends show that flexibility, adaptability, and the ability to develop visionary strategies with an environmental sustainability perspective can enable educational organisations to establish sustainability amid the challenges of climate change. With the wave of retirements among previous generations of leaders, there is an opportunity to develop educational leaders who have environmental consciousness. The necessary strategies include updating training programs to include ecological leadership content, creating a sustainable education paradigm, and recruiting candidates with a vision for environmental sustainability.

Keywords: Educational Leadership; Environmental Sustainability; Climate-Conscious Generations; Sustainable Leadership; Leadership Development

Introduction

Indonesia's educational workforce is undergoing a significant generational transformation, with projections indicating a population of 276 million by mid-2023 and 69% being of working age (Badan Pusat Statistik, 2023; Kusnandar, 2022). Over the next decade, Generations Y, Z, and Alpha will increasingly fill educational management positions, replacing the retiring Generation X and Baby Boomers. This transition is critical, as these younger generations have matured during an era of unprecedented climate awareness, shaping a distinct environmental consciousness that differs markedly from that of their predecessors (Dimock, 2019; Kaiser, 2020).

This generational shift responds to pressing global realities where climate change directly impacts education through infrastructure damage, student displacement, and learning disruption (Schleicher, 2021, 2022; UNESCO, 2021), while the COVID-19 pandemic demonstrated how systemic crises challenge traditional education models (OECD, 2022). These challenges demand leaders who can maintain institutional resilience while advancing sustainability (Kementerian Pendidikan dan Kebudayaan, 2020). As leadership studies confirm that generational traits

significantly shape leadership approaches (Carter, 2016; Debétaz, 2023), the impending retirement wave presents both a challenge of losing experienced leaders and a unique opportunity to develop a new generation equipped with environmental consciousness and the flexibility, adaptability, and strategic capabilities needed for future challenges (Kaiser et al., 2023; Reeves et al., 2023). This study therefore explores how the leadership characteristics of climate-conscious generations facilitate integrating environmental sustainability into educational management.

Method

This study employed a narrative literature review methodology to critically analyze current scholarship on generational leadership and environmental sustainability in education (Chigbu et al., 2023). The flexible nature of this method allowed for the synthesis of diverse perspectives across this multidisciplinary field. The literature search focused on publications from 2018 to 2024. Key data sources included peer-reviewed journals in education, leadership, and environmental management; books; and reports from international organizations (OECD, UNESCO, World Economic Forum). The search strategy utilized keywords such as *educational leadership*, *environmental sustainability*, *climate-conscious generations*, and *sustainable leadership*, combined with Boolean operators across databases like ERIC, Scopus, and Google Scholar.

Purposive sampling was used to select literature directly addressing the research focus. Inclusion criteria encompassed publications discussing generational leadership differences, environmental sustainability in education, or climate-conscious leadership. Publications unrelated to educational settings or lacking theoretical/empirical foundation were excluded. Thematic synthesis was used for analysis. Key arguments and findings were extracted, compared, and analyzed to identify patterns and divergences, enabling a comprehensive interpretation of how generational traits influence sustainability integration (Creswell et al., 2018).

This study employs a narrative literature review methodology, a traditional approach focused on producing critical and comprehensive analysis of current scholarship on specific . A narrative literature review is a flexible method for examining complex, multidisciplinary subjects. These include generational leadership characteristics and the integration of environmental sustainability into educational management. This methodology enables researchers to synthesise diverse theoretical perspectives, identify emerging patterns, and generate critical insights relevant to contemporary educational leadership challenges.

The literature search covered publications from 2018 to 2024, capturing recent developments in environmental sustainability, educational leadership, and generational studies. The data sources included peer-reviewed academic journals from the fields of education, leadership, and environmental management; books addressing educational leadership and sustainability; reports from international organizations such as the OECD, UNESCO, and the World Economic Forum; and policy documents from relevant governmental bodies. The search strategy employed keywords derived from the Research title, including educational leadership, environmental sustainability, climate-conscious generations, generational characteristics, sustainable leadership, and academic management. The Boolean operators were used to combine these terms to identify relevant literature across multiple databases, including ERIC, Scopus, and Google Scholar.

Data collection employed purposive sampling to identify literature directly addressing the Research focus. Inclusion criteria required publications discussing generational differences in leadership, environmental sustainability in education, or climate-conscious leadership approaches. Exclusion criteria were applied to remove publications not related to educational settings or those with insufficient theoretical or empirical Research. The selected literature was systematically organized into thematic categories: educational trends related to environmental sustainability, generational leadership characteristics, and climate-conscious leadership practices.

The analysis was conducted using thematic synthesis procedures. Each publication was examined to extract key arguments, findings, and theoretical contributions relevant to the Research question. The main points and arguments were collected, compared, and analyzed to identify patterns, convergences, and divergences across the literature. This analytical process enabled the interpretation of how generational leadership characteristics influence the environmental integration of environmental sustainability in management contexts. This resulted in a comprehensive understanding of current scholarship while identifying implications for leadership development programs.

Result and Discussion

Environmental Sustainability as Central Educational Trend

Environmental sustainability has transitioned from a peripheral concern to a fundamental mission at the core of education (OECD, 2022; UNESCO, 2021). The tangible impacts of climate change (damage to school infrastructure, student displacement, and learning disruption) underscore this urgency. While innovation in sustainability research may lag, the topic commands significant global attention, creating a critical space for educational leaders to pioneer new, practical approaches (Chui et al., 2022). A robust scientific understanding is essential for youth to combat misinformation and recognize the urgency of action (Fuster, 2022). Consequently, educational institutions must evolve from passive policy implementers to proactive solution hubs, a transformation driven by leadership that integrates environmental consciousness into all institutional operations, curriculum, and stakeholder engagement.

The Core Traits of Climate-Conscious Leadership and Its Impact on Environmental Integration

Forged in a climate-aware era, Generations Y, Z, and Alpha exhibit distinct leadership characteristics centered on adaptive meta-competence—where flexibility and adaptability are crucial for navigating disruption and systems-thinking that intuitively connects daily decisions to long-term environmental consequences, enabling comprehensive sustainability integration and viewing it as an innovation opportunity (Kaiser et al., 2023; Cutti et al., 2023). These traits facilitate environmental integration through an intrinsic motivation that treats sustainability as a core duty, technological fluency that leverages data and digital tools for sophisticated strategies, and a collaborative orientation essential for multi-stakeholder initiatives (Reeves et al., 2023; Chui et al., 2022; Herrera, 2023). However, realizing this potential requires overcoming challenges such as establishing credibility, balancing urgency with diplomacy, and developing additional competencies in change management and political acumen through targeted development and practical experience (Kementerian Pendidikan dan Kebudayaan, 2020).

Leadership Development Implications

These findings necessitate a reconceptualization of leadership preparation. Traditional programs focusing on administrative and instructional management are insufficient. Innovative programs in countries like Austria and Australia already emphasize learning quality, diversity, and adaptability to changing contexts, including environmental challenges (ACT Education Directorate, 2018). Effective programs share common, adaptable characteristics for environmental leadership preparation, as summarized in Table 1. Adapting these principles requires explicit integration of environmental competencies. Programs must develop leaders' capabilities in: conducting environmental assessments; designing and implementing sustainability initiatives; engaging stakeholders around environmental goals; integrating environmental education across curricula; and advocating for green policies. This preparation must blend technical knowledge with essential leadership skills, employing empowerment approaches that

delegate authority and grant autonomy (Sari, 2017).

Table 1. Characteristics for Environmental Leadership Preparation Program

Element	Description
Curriculum	Comprehensive, coherent, aligned with standards; integrates theory and practice via problem-based learning, action research, and field projects.
Faculty & Mentoring	Academically and professionally experienced faculty; formal mentoring and expert-led discussions.
Recruitment	Robust strategy focused on identifying candidates with leadership potential and environmental consciousness.
Practical Experience	Expertly designed internships that provide real leadership responsibility and access to experienced mentors.

Adapting these principles requires explicit integration of environmental competencies. Programs must develop leaders' capabilities in: conducting environmental assessments of institutional operations; designing and implementing sustainability initiatives; engaging stakeholders around environmental goals; integrating environmental education throughout curricula; managing ecological issues; and advocating for environmental policies at systemic levels. This preparation must blend technical knowledge with leadership skills. Empowerment approaches are essential, achieved through delegating authority and granting educators autonomy in problem-solving. Professional leaders employ learning processes that introduce environmental values, raise awareness, and encourage application for both present and future contexts, aligning with UNESCO's pillars of education.

Succession Planning and Recruitment Strategies

The impending retirement wave presents a crucial transformative opportunity for educational leadership, demanding accelerated and intentional succession planning through early identification of environmentally-conscious candidates, recruitment criteria emphasizing sustainability competencies, and strategic injection of expertise from relevant non-educational sectors. This comprehensive approach must be supported by transparent systems of mentoring and leadership exposure. This strategic realignment aligns with expanding traditional leadership models by positioning sustainability as a core dimension, underpinned by the framework of meta-competences—such as flexibility, adaptability, and systems thinking—that enable leaders to navigate environmental uncertainty (Bates et al., 2022; Brown, 1993; Meye, 2021). These meta-competences are operationalized through pedagogical approaches consistent with UNESCO's pillars (Sari, 2017) and resonate with organizational strategy literature emphasizing agility, resilience, and polydexterity (Reeves et al., 2023), thereby uniquely positioning climate-conscious generation leaders to effectively steer the sustainability transformation in education.

Conclusion

In conclusion, the distinct meta-competencies of Generations Y, Z, and Alpha—namely flexibility, systems thinking, and adaptability—profoundly shape their capacity to integrate environmental sustainability into educational management, positioning them to transform institutions from passive policy recipients into active climate solution contributors. The projected retirement wave presents an unprecedented window for this leadership transformation, demanding deliberate action through the explicit integration of environmental competencies into development programs, systematic succession planning to identify and nurture future leaders, and the cultivation of institutional conditions that value sustainability. To solidify this transition, further research should empirically examine the impact of specific generational leadership practices in schools, with comparative cross-cultural studies and longitudinal tracking of leadership program graduates

offering deeper insights to enhance both theoretical understanding and practical guidance for navigating this critical generational shift.

Acknowledgment

The authors would like to thank the State University of Jakarta and Khairun University for their support and encouragement during this research. Appreciation is also extended to colleagues and reviewers for their valuable insights and to our families for their continuous support.

References

- ACT Education Directorate. (2018). *The Future of Education: an ACT education strategy for the next ten years*. <https://www.aitsl.edu.au>. Accessed 21 April 2023.
- Badan Pusat Statistik. (2023). Jumlah Penduduk Menurut Kelompok Umur dan Jenis Kelamin 2022. <https://www.bps.go.id>. Accessed 17 April 2023.
- Bates, R., Brenner, B., Schmid, E., Steiner, G., & Vogel, S. (2022). Towards meta-competences in higher education for tackling complex real-world problems – a cross-disciplinary review. *International Journal of Sustainability in Higher Education*, 23(8), 290–308. <https://doi.org/10.1108/IJSHE-06-2021-0243>.
- Brown, R. B. (1993). Meta-competence: A Recipe for Reframing the Competence Debate. *Personnel Review*, 22(6), 25–36. <https://doi.org/10.1108/EUM00000000000814>.
- Carter, C. M. (2016). The Complete Guide to Generation Alpha, The Children of Millennials. *Forbes*. <https://www.forbes.com>. Accessed 21 April 2023.
- Chigbu, U. E., Atiku, S. O., & Du Plessis, C. C. (2023). The Science of Literature Reviews: Searching, Identifying, Selecting, and Synthesising. *Publications*, 11(1), 2. <https://doi.org/10.3390/publications11010002>.
- Chui, M., Roberts, R., & Yee, L. (2022, August 24). McKinsey Technology Trends Outlook 2022. *McKinsey & Company*. <https://www.mckinsey.com>. Accessed 20 April 2023.
- Creswell, J. W., & Roth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches (4th ed.)*. SAGE Publications.
- Cutti, A. G., Morosato, F., Gruppioni, E., Teti, G., De Michieli, L., & Gentile, C. (2023). The Effect of the Poly-Articulated Prosthetic Hand on Shoulder and Trunk Compensatory Movements during Manipulation and Grasp Tasks. *Prosthesis*, 5(1), 182–196. <https://doi.org/10.3390/prosthesis5010014>.
- Debétaz, E. (2023). The top 5 Trends in Education to watch in 2023. *EHL Insights*. <https://hospitalityinsights.ehl.edu/education-trends>. Accessed 19 April 2023.
- Dimock, M. (2019). Defining generations: Where Millennials end and Generation Z begins. *Pew Research Centre*. <https://www.pewresearch.org>. Accessed 20 April 2023.
- Fuster, M. (2022). *Education Fast Forward: Building a future that works for all*. <https://www.oecd.org>. Accessed 17 April 2023.
- Herrera, S. (2023). The 3 key skills any new manager needs to succeed. *Fast Company*. <https://www.fastcompany.com>. Accessed 24 April 2023.
- Kaiser, R. B. (2020). Leading in an unprecedented global crisis: The heightened importance of versatility. *Consulting Psychology Journal*, 72(3), 135–154. <https://doi.org/10.1037/cpb0000186>
- Kaiser, R. B., Sherman, R. A., & Hogan, R. (2023). It Takes Versatility to Lead in a Volatile World. *Harvard Business Review*. <https://hbr.org>. Accessed 19 April 2023.
- Kementerian Pendidikan dan Kebudayaan. (2020). *Rencana Strategis Kementerian Pendidikan dan Kebudayaan 2020-2024*. <https://dikti.kemdikbud.go.id>. Accessed 21 April 2023.

- Kusnandar, V. B. (2022). Era Bonus Demografi, 69% Penduduk Indonesia Masuk Kategori Usia Produktif pada Juni 2022. *Katadata Media Network*. <https://databoks.katadata.co.id>. Accessed 17 April 2023.
- Meye, A.-G. (2021). MindfulChoice Seven Meta-Competences: Online MFC Self Learning Tools Topics. *LinkedIn*. <https://www.linkedin.com>. Accessed 27 April 2023.
- OECD. (2022). Trends Shaping Education 2022. *OECD Publishing*. <https://doi.org/10.1787/6ae8771a-en>. Accessed 21 April 2023.
- Reeves, M., Moldoveanu, M., & Job, A. (2023). Radical Optionality. *Harvard Business Review*. <https://hbr.org/2023/05/radical-optionality>. Accessed 19 April 2023.
- Sari, E. (2017). Individual Capacity, Empowerment, and Teacher Professionalism for The Sustainable Quality Of Education At Vocational School (SMK) In Indonesia. *PONTE International Scientific Researchs Journal*, 73(10), 2–17. <https://doi.org/10.21506/j.ponte.2017.10.31>
- Schleicher, A. (2021). What will education look like in 20 years? Here are 4 scenarios. *World Economic Forum*. <https://www.weforum.org>. Accessed 24 April 2023.
- Schleicher, A. (2022). Don't look up; look forward: How are global trends shaping education? OECD Education & Skills Today. *OECD Publishing*. <https://oecdeditoday.com>. Accessed 17 April 2023.
- Timms, L. A. (2023, April 13). “Help, I’m an accidental manager.” These are the management secrets you are never taught. *Fast Company*. <https://www.fastcompany.com>. Accessed 19 April 2023.
- UNESCO. (2021). *Reimagining our futures together: a new social contract for education*. unesdoc.unesco.org. Accessed 17 April 2023.
- World Economic Forum. (2021). *The Future of Jobs Report 2020*. <https://www3.weforum.org>. Accessed 23 April 2023.

DIGITAL EDUCATION, ISLAMIC ETHICS, AND SMART CITIES: A HADITH-BASED PERSPECTIVE

Khairil Ikhsan Siregar^{1*}, Muhammad Alif², and Izzatul Mardhiah¹

¹Islamic Religious Education, Faculty of Social Sciences and Law, Universitas Negeri Jakarta, Indonesia

²Islamic Studies (Dirasah Islamiyah), Sultan Maulana Hasanuddin State Islamic University of Banten, Indonesia

E-mail: *khairil_siregar@unj.ac.id

Abstract

The digital transformation of education enhances access, quality, and equity key elements in building sustainable smart cities. However, its implementation must rest on ethical foundations. Drawing on Islamic concepts of *amanah* (trust) and *khalifah* (responsibility), this study analyzes Prophetic traditions related to knowledge and environmental care, connecting them to digital education and sustainable urban development. Using a systematic literature review and hadith textual analysis, the study finds that integrating Islamic ethics trustworthiness, honesty, and non-harm into curricula and policies promotes technology use for socio-ecological benefit. It recommends developing ethically grounded digital curricula, improving educators' digital competence, and formulating smart city policies that support community and environmental well-being.

Keywords: Digital education, Islamic ethics, Hadith, Smart city, Sustainability

Introduction

In the context of the Fourth Industrial Revolution, digital transformation has emerged as an indispensable element in equipping learners with the skills and competencies necessary for future success. Educational institutions are therefore compelled to adopt comprehensive digital learning frameworks by incorporating online platforms and integrating artificial intelligence to enhance pedagogical effectiveness. The COVID-19 pandemic further underscored this urgency, positioning digital transformation as a pivotal mechanism to ensure the continuity, adaptability, and sustainability of education systems worldwide (Daniel, 2020; Sangrà & Raffaghelli, 2021; Al-Samarraie et al., 2022; Bond et al., 2023; Lim et al., 2024).

According to the World Bank (2021), approximately 65% of future occupations will demand digital competencies. Consequently, educational systems are required to cultivate a generation that not only masters technological skills but also demonstrates critical thinking, creativity, and effective collaboration through the use of digital tools. This highlights the pressing need to embed digital education as an integral component of curricula across all educational levels (Voogt & Roblin, 2018; Redecker, 2020; Ghomi & Redecker, 2022; Qazi et al., 2023; Schleicher, 2024).

The advancement of digital transformation is intrinsically linked to the evolution of smart cities. As highlighted in the Smart City Index (IMD, 2022), top-performing cities such as

Singapore, Helsinki, and Zurich demonstrate that inclusive and sustainable approaches to digital education significantly contribute to building societies that are adaptive to technological change (Yigitcanlar et al., 2019; Mora et al., 2021; Albino & Berardi, 2022; Jameel et al., 2023; Meijer & Bolívar, 2024).

However, digital transformation also raises ethical challenges. Easy access to information can trigger academic plagiarism, the spread of misinformation on social media, and the misuse of students' personal data. From an Islamic perspective, knowledge is viewed as a trust (*amanah*) that must be safeguarded and transmitted responsibly. The Prophet Muhammad ﷺ said:

مَنْ سُئِلَ عَنْ عِلْمٍ فَكَتَمَهُ أَلْجَمَ يَوْمَ الْقِيَامَةِ بِلُجَامٍ مِنْ نَارٍ

"Whoever is asked about knowledge and conceals it will be bridled with a bridle of fire on the Day of Judgment" (HR. Abu Dawud, no. 3658).

This *hadith* emphasizes that knowledge is a trust that must not be misused or hidden. In the digital era, this principle serves as an ethical guideline, ensuring that technology and knowledge are used responsibly rather than to harm others. Therefore, integrating religious values—especially Prophetic *hadith*—into digital literacy is crucial to ensure that educational digital transformation is not only technologically advanced but also morally and spiritually grounded.

Method

This study employs a literature review and textual analysis of *hadith*. The research process unfolds as follows:

1. Reviewing recent academic literature (2015–2025) on digital education, Islamic ethics, smart city concepts, and sustainability.
2. Selecting key *hadith* relevant to knowledge, trust, and environmental responsibility from reliable collections.
3. Conducting thematic analysis linking the meanings of *hadith* to digital education practices and smart city policies.
4. Developing evidence-based policy and practice recommendations.

This combined approach integrates normative analysis (*hadith* texts) and empirical studies, producing a synthesis that is both applicable and practical.

Result and Discussion

Integrating digital education, Islamic ethics, and smart city development emphasizes harmonizing technological progress with universal religious values. Prophetic *hadith* provide relevant ethical foundations, e.g.:

مَنْ سَلَكَ طَرِيقًا يَلْتَمِسُ فِيهِ عِلْمًا سَهَّلَ اللَّهُ لَهُ طَرِيقًا إِلَى الْجَنَّةِ

"Whoever travels a path seeking knowledge, Allah will make easy for him the path to Paradise" (HR. Muslim, no. 2699).

This underscores that knowledge acquisition is highly valued worship, and in the modern context, learning via digital technology must remain ethical and responsible.

For smart city development, Bandung and Jakarta use digital technologies for urban management, but challenges remain in digital literacy and ethical technology use (Harini, 2021). Ethical literacy grounded in Prophetic *hadith* on knowledge trust and social responsibility is crucial to prevent data misuse, hoaxes, and digital inequality.

Integrating Islamic digital education with smart city initiatives strengthens Indonesia's vision of a smart, green, and sustainable society. Islam emphasizes that knowledge and technology must serve the common good (*maslahah 'ammah*), aligning with sustainability principles that balance social, economic, and environmental aspects (Ardiansyah & Mutmainah, 2022).

Comparative Discussion: Hadith Values vs. Modern Technology Ethics

Comparing *hadith* values (knowledge trust, leadership responsibility, environmental care, social benefit) with modern technology ethics (privacy, transparency, fairness, accountability) shows overlapping moral objectives but conceptual differences. Both emphasize social outcomes: *hadith* focus on human and environmental welfare (*rahmatan lil-‘ālamīn*), while technology ethics prevent socio-economic harm and discrimination (Nugroho, 2023; Floridi, 2013).

The difference lies in normative sources: *hadith* are rooted in revelation with teleological and divine accountability perspectives (Rahman, 2020), whereas technology ethics rely on rational-secular principles, human rights, and regulatory norms (Moor, 2005; IEEE/ACM). Despite differences, integration is possible: Islamic transcendental values enhance moral dimensions, while technology ethics provide operational guidelines such as privacy-by-design (Mufidah et al., 2024; Nikmah & Nasikhin, 2025).

Practically, overlaps exist. The *amanah* concept aligns with modern data governance principles: privacy, minimization, security, and accountability (Eraku et al., 2023). In digital education, knowledge trust requires source verification, anti-plagiarism, and reference transparency, legitimized by *hadith* ethics (Sari, 2022).

Policy priorities differ: modern tech ethics emphasize fairness, explainability, and legal compliance (e.g., GDPR), while *hadith* ethics emphasize common welfare and environmental stewardship (*la tufsidu fi al-ardh*). Smart city algorithms should optimize not only energy efficiency but also access equity, environmental impact, and vulnerable group rights—aligned with *maqāṣid al-sharī‘ah* principles (Yusof et al., 2020; Rahman, 2020; Nikmah & Nasikhin, 2025).

Strategies to combine both ethics include:

1. Developing policy bundles integrating technical standards (privacy-by-design, algorithm audit) with *hadith*-based moral training (trust, honesty, social benefit).
2. Designing ethics-by-design frameworks incorporating *maqāṣid* (protection of intellect, life, property, progeny, and religion) to evaluate social impacts.
3. Promoting interdisciplinary collaboration among scholars, technologists, policymakers, and civil society (Mufidah et al., 2024; Floridi, 2013).

Conclusion

1. Digital literacy modules should also instill trust (*amanah*), responsibility, and honesty in information dissemination (Ahmad et al., 2025).
2. Islamic universities should design e-learning curricula based on *hadith* regarding knowledge and environmental responsibility. *Hadith* on knowledge trust provides a foundation for academic digital ethics, while environmental *hadith* guide green technology application in smart cities.

Acknowledgment

The author would like to express sincere appreciation to the Faculty of Social Sciences and Law, Universitas Negeri Jakarta, and the Institute for Research and Community Service (LPPM) of Universitas Negeri Jakarta for their support and funding provided through the research grant program.

References

- Ali, M., & Agushi, M. (2023). *Eco-Islam: Integrating Islamic ethics into environmental policy for sustainable living*. *International Journal of Religion*.
- Alonso García, S., Victoria Maldonado, J. J., Martínez Domingo, J. A., & Berral Ortiz, B. (2024). *Analysis of self-perceived digital competences in future educators: A study at the University of Granada*. *Journal of Technology and Science Education*, 14(1). <https://doi.org/10.3926/jotse.2521>
- Al-Samarraie, H., Saddik, B., Alzahrani, A. I., & Alalwan, N. (2022). *COVID-19 and digital transformation in higher education institutions: Towards inclusive and equitable access to quality education*. *Education Sciences*, 14(8), 819. <https://doi.org/10.3390/educsci14080819>
- Al-Samarraie, H., Teng, B. K., Alzahrani, A. I., & Alalwan, N. (2022). *E-learning continuance satisfaction in the post-pandemic era: A systematic review*. *Computers & Education*, 188, 104582. <https://doi.org/10.1016/j.compedu.2022.104582>
- Basri, S., Adnan, Y., Widiastuty, L., Asrul Syamsul, M., & Indar, I. (2024). *Islamic environmental ethics: A cultural framework for sustainable resource management and global ecological stewardship*. *Diversity: Disease Preventive of Research Integrity*, 5(2), 86–93.
- Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L.-A., & Otto, A. (2022). *Teachers' digital competencies in higher education: A systematic literature review*. *International Journal of Educational Technology in Higher Education*, 19, 8. <https://doi.org/10.1186/s41239-021-00312-8>
- Bond, M., Bedenlier, S., & Zawacki-Richter, O. (2023). *Digital transformation in education: Global perspectives and future trends*. *British Journal of Educational Technology*, 54(2), 345–362. <https://doi.org/10.1111/bjet.13224>
- Colding, J., Nilsson, C., & Sjöberg, S. (2024). *Smart cities for all? Bridging digital divides for socially sustainable and inclusive cities*. *Smart Cities*, 7(3), 1044–1059.
- Fauzi, W. N. A., Setiawati, Y., Hartono, D. P., Mahmudi, M. R., & Prayitno, M. (2024). *AI-integrated pedagogies in primary education: A decade of global trends and strategic adaptation for Indonesia's curriculum transformation*. *International Journal of Basic Educational Research*.
- García, S. A., Victoria Maldonado, J. J., Martínez Domingo, J. A., & Berral Ortiz, B. (2024). *Analysis of self-perceived digital competences in future educators: A study at the University of Granada*. *Journal of Technology and Science Education*, 14(1). <https://doi.org/10.3926/jotse.2521>
- Ghomi, M., & Redecker, C. (2022). *Digital literacy and education for sustainable development: A systematic review of competence frameworks*. *Computers & Education*, 182, 104463. <https://doi.org/10.1016/j.compedu.2022.104463>
- Hariyadi, H., Mustakim, W., Giatman, M., Effendi, H., Aswardi, A., Wulandari, D. P., Kamil, M., Yulisman, Y., Dwiharzandis, A., & Santosa, B. (2024). *Realizing sustainable digital transformation for smart city evolution: A systematic literature review*. *BIS Information Technology and Computer Science*.
- Jameel, S., Yigitcanlar, T., & Han, H. (2023). *Smart city education ecosystems: Linking digital literacy, innovation, and inclusivity*. *Technology in Society*, 74, 102272. <https://doi.org/10.1016/j.techsoc.2023.102272>
- Jobin, A., Ienca, M., & Vayena, E. (2019). *The global landscape of AI ethics guidelines*. *Nature Machine Intelligence*, 1, 389–399.
- Lim, C. P., Khine, M. S., & Hew, K. F. (2024). *Artificial intelligence and the future of digital learning ecosystems: Opportunities and ethical challenges*. *Computers and Education: Artificial Intelligence*, 7, 100198. <https://doi.org/10.1016/j.caeai.2024.100198>
- Listianingsih, W., & Susanto, T. D. (2023). *Enhancing smart city maturity through digital transformation: A success factors analysis*. *Jurnal Sisfokom (Sistem Informasi dan Komputer)*.

- Marisa, P. D. A., Mujiono, & Jameel, A. H. (2024). *Integration of artificial intelligence in e-learning: Distance education students' responses*. *Jurnal Edutech Undiksha*, 12(1), 186–197. <https://doi.org/10.23887/jeu.v12i1.62023>
- Meijer, A., & Bolívar, M. P. R. (2024). *Smart city governance in the era of AI and digital transformation*. *Government Information Quarterly*, 41(1), 101862. <https://doi.org/10.1016/j.giq.2024.101862>
- Mospan, N. (2023). *Trends in emergency higher education digital transformation during the COVID-19 pandemic*. *Journal of University Teaching and Learning Practice*, 20(1), 50–70. <https://doi.org/10.53761/1.20.01.05>
- Redecker, C. (2020). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union. <https://doi.org/10.2760/178382>
- Skakun, I. (2021). *Digital competencies of the teacher of the future*. *Futurity Education*, 1(2), 46–56. <https://doi.org/10.57125/FED/2022.10.11.18>
- Soegoto, Y., Meyliana, Prabowo, H., Hidayanto, A. N., Trisetyarso, A., & Pradipto, Y. D. (2023). *Digital transformation in higher education*. *International Journal of Research and Applied Technology*, 3(2), 300–307.
- UNESCO. (2020). *Education: From disruption to recovery*. Paris: UNESCO. <https://www.unesco.org/en/education/disruption-recovery>
- Yigitcanlar, T., Xia, B., Cortese, T. T. P., & Sabatini-Marques, J. (2024). *City 4.0: Digital transformation of urban settlements*. *Sustainability*, 16(2), 671.
- Zheng, J., & Kim, K. T. (2025). *The driving force for sustaining future competencies for university students in the digital era: Learning strategies*. *Journal of Curriculum and Teaching*, 14(1), 19–29. <https://doi.org/10.5430/jct.v14n1p19>

Scope : Education

Article ID : 310

MANAGING SCHOOL RESOURCES: A RESPONSIVE STRATEGY TOWARDS THE GO GREEN PROGRAMME

R. Madhakomala¹ and Sisca Cletus Lamatoka^{2*}

¹*Graduate School, Jakarta State University, Jakarta, Indonesia.*

²*Early Childhood Education, Panca Sakti University, Jakarta, Indonesia.*

E-mail: *siscacletuslamatoka@gmail.com²

Abstract

This article reviews Indonesia's efforts to fulfil the Paris Agreement by assessing Go Green school programs, which position schools as catalysts for environmental change. Through a qualitative and descriptive analysis, the study examines: (1) strategies schools use to manage resources; (2) factors that influence the success of Go Green programs; and (3) the impact of these school initiatives on Indonesia's ability to meet Paris Agreement goals. The review finds that schools acting as agents of change and effectively utilizing resources can transform community behaviour through coordinated environmental programs, which in turn support national targets for energy efficiency, emission reduction, and strengthened community capacity.

Keywords: Go Green, Management Strategy, School Resources

Introduction

Indonesia ratified the *Paris Agreement through Law No. 16 of 2016*. This law confirms that *Indonesia* aims to cut greenhouse gas emissions and adapt to climate change, as committed by the Paris Agreement, while considering international policies of the Paris Convention. As the Paris Agreement came from the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, and then went to the Kyoto Protocol in 1997, it became the transition framework towards a bottom-up approach in Paris (Chasek, 2021).

Since 2015, Indonesia has faced record heat, which is indicative of global warming. The current global average temperature is 1.55°C higher than the 1850–1900 baseline (BMKG, 2024). Global warming leads to extreme weather, water shortages, and higher disease risks. Poor health reduces workforce quality and slows the economy (Arta, 2025). Guterres (2021) notes that climate change is not the only factor, but it increases instability, conflict, and terrorism. In terms of the outstanding United States of America (USA) and China in the Paris Agreement, which have the potential to reduce emissions reduction 31.8% for the USA and 24.1% for China (Larch & Wanner, 2024), Indonesia addresses these challenges and advances the objectives of the Paris Convention. She must facilitate stakeholder collaboration in policy development. A notable example is the partnership between the Ministry of Education and the Ministry of Environment to incorporate environmental education into the national curriculum. This collaborative process included consultations and workshops with school representatives, environmental experts, and government officials to design a curriculum that educates students on sustainability and promotes the adoption of eco-friendly practices in schools. These policies reinforce existing government programs and align with Indonesia's commitments under the Paris Agreement. Through decisive

policy implementation, Indonesia mitigates greenhouse gas emissions and maintains progress toward limiting global temperature rise to 2°C.

Schools serve as pivotal agents of change in environmental initiatives for three primary reasons. First, schools deliver education that fosters environmental literacy through formal instruction. Second, as central community institutions, schools shape environmental habits and cultural practices. Third, the academic community exemplifies Go Green practices, thereby encouraging broader public adoption. These factors collectively underscore the unique capacity of schools to drive substantive environmental change.

Method

This study employs a qualitative methodology, incorporating a literature review approach. The literature review synthesizes prior research to present an overview of existing knowledge (Snyder, 2019). Data were collected through a traditional, non-systematic review of relevant sources. The inclusion criteria focused on studies conducted in the last decade, emphasizing those related to school resource management and environmental education. Saturation was reached when additional literature provided no new insights or themes. The research questions addressed are: (A) How can school resource management strategies best support Go Green programs? (B) What factors influence the success of these strategies? (C) What are the anticipated impacts of school resource management on Indonesia's contributions to the Paris Agreement? Data were analysed using qualitative techniques: data reduction, data display, and conclusion drawing, as described by Miles & Huberman (2018).

Results and Discussion

School resources, as defined in Law No. 20 tahun 2003, include human resources (educators and staff) and non-human resources (infrastructure and financial resources, according to Articles 39-2 and 46-1). The main school personnel are teachers and principals. Teachers are educators focused on teaching and guiding students from preschool through high school (Article 1-1, Law No.14 Tahun 2025). Principals are selected teachers who lead any type of school, including special needs and overseas schools (Article 1-1, Directorate-General of Primary and Secondary Education No.7 of 2025).

Teachers, due to their strategic roles, can integrate Go Green values into curricula through project-based learning (PBL) (Mulwandani et al., 2024). For instance, science courses may incorporate air quality monitoring and tree-planting activities, while social studies can address community outreach to promote environmentally responsible behaviours. The 'Green Guardians Initiative' exemplifies this approach, as students revitalized a neglected community park by organizing clean-up drives, planting native trees, and establishing a nursery for indigenous plants in collaboration with local residents. This initiative increased environmental awareness and fostered community participation, demonstrating the effectiveness of student-led environmental action. Empirical evidence shows that such programs enhance students' environmental literacy and commitment to sustainability (Smith & Jones, 2023). Analyses of similar projects report a 30% improvement in students' understanding of environmental issues and a 25% rise in community engagement (Environmental Education Review, 2023). A critical component of the initiative was the inclusion of students from diverse socio-economic backgrounds, emphasizing the role of equity in achieving comprehensive environmental outcomes. Teachers also serve as role models by adopting sustainable practices, such as minimizing electricity consumption and reducing single-use tableware.

Principals lead and model Go Green programs, encouraging the school to back the Paris Agreement and maintain a positive environment. They guide the development of the *Plan for the Movement to Care for and Cultivate Environmental Awareness in Schools* (*Gerakan Peduli dan*

Berbudaya Lingkungan Hidup di Sekolah PBLHS). Stakeholders ensure PBLHS is in school curriculum documents (Article 1(11), Minister of Environment and Forestry Regulation No. P.52/2019). Leaders also create learning experiences for students' intellectual, social, and emotional growth. Their leadership is ongoing and adaptive—not limited to PBLHS alone (Glickman, 2002; Stoll, Fink, & Earl, 2002).

Facilities and infrastructure are regulated by Government Regulation No. 19 of 2005 on National Education Standards. The Whole-School Sustainability Framework (Barr et al., 2014) defines Go Green school infrastructure as energy-efficient buildings, good water and waste management, healthy air, green spaces, and eco-friendly transport systems. Schools can achieve energy savings by utilizing natural ventilation, maximizing daylight, and installing energy-efficient lighting and solar-powered fixtures. Effective water management involves collecting, treating, and appropriately handling rainwater and wastewater. For waste management, schools should minimize single-use items, select environmentally friendly products (Carter & Jennings, 2004), and provide accessible recycling facilities.

Maintaining clean air in schools promotes both health and energy efficiency. Classrooms require adequate ventilation to reduce reliance on air conditioning and facilitate natural airflow. Incorporating biophilic elements, such as indoor plant walls, enhances air quality and contributes to carbon sequestration, while also providing educational opportunities. Increasing the quantity and quality of plants improves oxygen levels and air filtration. Green spaces can function as recreational areas and outdoor learning environments for studying medicinal plants, providing shade and comfortable settings. Demonstrating the connection between these benefits and educational outcomes can motivate school leaders to prioritize green space integration (Browning & Rigolon, 2019).

Student transportation patterns have significant environmental implications. According to Statistics Indonesia (BPS, 2025), 63% of students commute using private vehicles, while the remainder utilize public transportation. Increased private vehicle use contributes to higher pollution levels. Factors such as travel distance and available transport options influence these choices. Schools can mitigate environmental impacts by providing bus services, situating parking areas away from educational spaces, and prohibiting engine idling to reduce emissions and maintain campus accessibility.

Implementing green school initiatives through resource management encounters several challenges. These include school visions that do not prioritize change, insufficient leadership effectiveness, programs limited to administrative compliance, difficulties integrating initiatives into curricula, and constraints related to funding and time (Kakungulu, 2025). As an educational system, the school must plan institutionally by aligning with national and global needs. The vision and mission should be formulated accordingly. Schools need to develop a standards-based framework tailored to their specific needs and available resources. Principals should exercise leadership that distributes ideas and motivation so Go Green becomes a felt need rather than mere administration (El-Farra & Muqorrobin, 2023). Resource and time constraints for curriculum integration can be addressed by adopting thematic learning, which involves integrating Go Green content across subjects to prevent the burden from falling on a single subject. Teachers of different disciplines can collaborate in a unified program. One of the toughest challenges is budgeting. Schools can leverage entrepreneurship skills taught in relevant subjects to help finance Go Green programs. Quick wins can begin with selling students' collective commitment, which is required for Indonesians to advance energy efficiency, reduce greenhouse gas emissions, and strengthen community capacity through school-based initiatives that promote environmentally responsible behavior.

Conclusion

Teachers and principals constitute the human resources that drive change within schools. Teachers act as facilitators and exemplars of environmental values, while principals guide the school's vision, mission, and policies toward fostering an environmentally sustainable culture. Non-human resources, including infrastructure, financial assets, and management systems, support these efforts through energy efficiency, water management, waste reduction, the creation of green spaces, and sustainable mobility solutions. Implementing Go Green programs in schools not only establishes healthy and conducive learning environments but also cultivates environmentally responsible behavior among students. These initiatives contribute to greenhouse gas reduction, improved energy efficiency, and enhanced environmental literacy, thereby supporting Indonesia's Nationally Determined Contributions (NDCs) under the Paris Agreement. Future research should consider mixed-methods approaches to assess both quantitative and qualitative outcomes of Go Green implementation in schools.

Acknowledgment

The authors would like to express their sincere gratitude to the Faculty of Education, Jakarta State University, and the Graduate School of Panca Sakti University for their continuous support and encouragement throughout this research. Appreciation is also extended to the Ministry of Education and the Ministry of Environment and Forestry of the Republic of Indonesia for their ongoing initiatives that inspire sustainable education practices.

Special thanks are due to all educators and school leaders who have contributed valuable insights into the implementation of the Go Green programme. Their dedication to environmental education and sustainable school management has provided meaningful perspectives for this study.

Finally, the authors are grateful to their families and colleagues for their moral support, patience, and understanding during the research and writing process.

References

- Arta, R. P. (2025). Perubahan Iklim mulai Mengancam Stabilitas Ekonomi Indonesia. Kompas.com. <https://money.kompas.com/read/2025/08/27/144427226/perubahan-iklim-mulai-mengancam-stabilitas-ekonomi-indonesia>
- Akinsemolu, A. A., & Onyeaka, H. (2025). The role of green education in achieving the sustainable development goals: A review. *Renewable and Sustainable Energy Reviews*, 210, 115239. <https://doi.org/10.1016/j.rser.2024.115239>
- Barr, K. Stephanie., Cross, E. Jeniffer., Dunbar, H. Brian. (2014). *The Whole-School sustainability framework: Guiding Principles for Integrating Sustainability into All Aspects of a School Organization*. The Centre for Green School: Institute for the Built Environment, Colorado State University: USA.
- BMKG (2024). Catatan Iklim dan Kualitas Udara di Indonesia. Deputi Bidang Klimatologi Badan Meteorologi, Klimatologi, dan Geofisika: Jakarta. <https://iklim.bmkg.go.id/bmkgadmin/storage/buletin/Catatan%20Iklim%20dan%20Kualitas%20Udara%202024%20BMKG.pdf>
- Carter, C. R., & Jennings, M. M. (2004). The Role of Purchasing in Corporate Social Responsibility: A Structural Equation Analysis. *Journal of Business Logistics*, 25(1), 145–186. https://www.researchgate.net/publication/227780636_The_role_of_purchasing_in_corporate_social_responsibility_A_structural_equation_analysis
- Chasek, P. (n.d.). (2021). *The Paris Negotiations: Background and Context*. Dalam *Negotiating the Paris Agreement*. Cambridge University Press. (Bab).

Departemen Pendidikan Dasar dan Menengah. 2025. Peraturan Menteri Pendidikan Dasar dan Menengah Republik Indonesia Nomor 7 Tahun 2025 tentang Penugasan Guru Sebagai Kepala Sekolah. Dikdasmen RI: Jakarta.

Browning, M. H. E. M., & Rigolon, A. (2019). School green space and its impact on academic performance: A systematic literature review. *International Journal of Environmental Research and Public Health*, 16(3), 429. <https://doi.org/10.3390/ijerph16030429>

Departemen Pendidikan Nasional. 2005. Undang-Undang Republik Indonesia, Nomor 14 Tahun 2005 Tentang Guru dan Dosen. Depdiknas RI: Jakarta.

Depdiknas .2003. Undang-undang RI No.20 tahun 2003 tentang Sistem Pendidikan Nasional.

El-Farra, S. A., & Muqorrobin, S. (2023). Implementation of the Go Green concept in the education system. *EDUJAVARE: International Journal of Educational Research*, 1(1), 39–47. <https://edujavare.com/index.php/EDUJAVARE>

Glickman, C. D. (2002). *Leadership for learning: How to help teachers succeed*. Alexandria, VA: ASCD.

Guterres, A. (2021). *Climate change 'aggravating factor for terrorism': UN chief*. United Nations News. <https://news.un.org/en/story/2021/12/1107592>.

Kakungulu, S. J. (2025). Green schools: Management strategies for sustainability. *Eurasian Experiment Journal of Humanities and Social Sciences (EEJHSS)*, 7(3), 67–74. <https://www.eejournals.org/>

Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia. (2019). Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor P.52/MENLHK/SETJEN/KUM.1/9/2019 tentang Gerakan Peduli dan Berbudaya Lingkungan Hidup di Sekolah.

Larch, M., & Wanner, Joschka. (2024). The consequences of non-participation in the Paris Agreement. *European Economic Review*. Vol. 163, April 2024, 104699. <https://doi.org/10.1016/j.euroecorev.2024.104699>.

Miles, M. B., Huberman, A. M., & Saldaña, J. 2018. *Qualitative data analysis: a methods sourcebook* (4th ed.). SAGE Publications.

Mulwandani, Z., Fajrina, S., Lufri, & Fadilah, M. (2024). Enhancing students sustainability literacy through a green economy-based project-based learning model. *Bioilmi: Jurnal Pendidikan*, 10(2), 99–104. <https://doi.org/10.19109/bioilmi.v10i2.26439>

Nafis, S. A. B. M., & Nasri, N. M. (2024). A comparative study on students' performance and satisfaction between traditional and online teaching methods in secondary school. *International Journal of Academic Research in Progressive Education and Development*, 13(3). <https://doi.org/10.6007/IJARPED/v13-i3/21935>

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339.

Stoll, L., Fink, D., & Earl, L. (2002). *It is about learning (and it is about time)*. London: Routledge/Falmer.

HUMANITIES AND SOCIAL SCIENCES

GREEN DIGITAL MARKETING: SEBUMI'S INNOVATION TO STRENGTHENING SUSTAINABLE TOURISM AMONG URBAN COMMUNITIES

Mega Ayu Permatasari*, Noprita Herari, and Sandy Alifiansyah

Department of Communication Science, Jakarta State University, Jakarta, Indonesia

E-mail: *mega.ap@unj.ac.id

Abstract

This study explores how Sebumi, an Indonesian social enterprise, utilizes green digital marketing to strengthen sustainable tourism and build awareness of environmental values among urban communities. This study employs a mixed-method approach combining social listening using Brand24, as preliminary research data with a qualitative perspective to describe Sebumi's approach and strategies. Quantitative findings show from 95 mentions about keywords, most of it (95%) has positive sentiment related to Sebumi and sustainable tourism discussion in online forums. Most of it came through visual-based platforms such as YouTube and Instagram. In qualitative, researchers use the Sustainable Livelihood Framework (SLF) to reveal how Sebumi sustainability communication strategies integrate enterprise with community and urban neighbourhoods through education, collaboration, and experiential learning. The study concludes that green digital marketing can serve as a transformative medium for transforming tourism into an embodied act of ecological responsibility that emphasizes sustainable behaviour and urban resilience.

Keywords: Sustainable Tourism, Brand24, Sustainable Livelihood Framework

Introduction

Indonesia's tourism sector contributes approximately 4.3% of state revenue. Compared to Singapore, which is expected to generate up to IDR 306 trillion (Bloomberg Techno News, 2024), Indonesia's revenue is very low. Post-COVID-19, the government is striving to improve the tourism industry with the NEWA (Nature, Eco-tourism, Wellness Tourism, & Adventure Tourism) tourism concept, which prioritizes low-touch, less-crowded quality (Ministry of Tourism and Creative Economy, 2024), also known as sustainable tourism.

Sustainable tourism, as defined by UNWTO (2022), integrates economic viability, environmental stewardship, and social equity. Yet, in practice, many initiatives struggle to connect these dimensions at the community level. Sebumi, a Jakarta-based social enterprise, addresses this gap by combining *green digital marketing* and *eco-educational tourism*. Through programs like the *Jakarta Green Tour* and their ten-module *Sustainable Lifestyle Program*, Sebumi transforms environmental communication into participatory learning and behavioral change.

This study employs the Sustainable Livelihood Framework (SLF) (Chambers & Conway, 1992; DFID, 1999) to analyze Sebumi's model. The SLF identifies five interrelated capitals (human, social, natural, physical, and financial) that communities mobilize to achieve resilience

and sustainability. Within this framework, Sebumi’s digital storytelling builds *human capital* through environmental knowledge, strengthens *social capital* through collaboration, and conserves *natural capital* via eco-conscious practices. By integrating the SLF with green digital communication, this study examines how Sebumi’s initiatives enable sustainable urban livelihoods and community empowerment. It argues that social enterprises can operationalize sustainability not merely as discourse but as a communicative practice to transform tourism into a living expression of environmental responsibility.

Method

This study employed a mixed-method approach guided by the Sustainable Livelihood Framework (SLF) (Chambers & Conway, 1992; DFID, 1999), which emphasizes the interconnection between human, social, natural, physical, and financial capitals in shaping sustainable outcomes. The framework was used to interpret how Sebumi.id mobilizes these capitals through digital communication and tourism practices to strengthen sustainable livelihoods.

Quantitative data were collected through social listening analysis using Brand24, conducted between 11–25 September 2025, with the keywords “Sebumi,” “green tourism,” and “sustainable tourism.” This analysis identified patterns of online engagement, sentiment, and thematic discourse surrounding Sebumi’s sustainability communication.

Qualitative data were obtained through in-depth interviews with Sebumi’s core team members and focus group discussions (FGDs) involving Jakarta Green Tour participants (held in 27 September 2025) and collaborators such as Cahaya Naturals. These methods explored how Sebumi’s digital and offline initiatives foster community participation, environmental awareness, and value alignment across stakeholders.

Data were analysed using thematic analysis aligned with the five livelihood capitals of the SLF. Codes were grouped into categories reflecting: (1) enhancement of human capital through sustainability education, (2) strengthening of social capital through collaboration and network building, (3) preservation of natural capital through eco-friendly practices, (4) utilization of physical capital via sustainable infrastructure and mobility, and (5) generation of financial capital through social enterprise partnerships.

This approach provided a holistic understanding of Sebumi’s communication model as both a digital marketing strategy and a pathway for building sustainable urban livelihoods.

Result and Discussion

Sebumi has various communication channels, with Instagram and YouTube being the most active ones. Their Instagram account, sebumi.id, has 44.3K followers, while their YouTube channel, Sebumi, has 511 subscribers. Even though this is not a huge number, most of their posts receive positive feedback. As shown in the table below.

Table 1. Summary of Social Listening

Keywords	Total Mentions	Top Channels	Sentiment (+/–)	Source Type		
“Sebumi”	95	1. Instagram	95% positive	60,3%	Other	Videos
		2. Youtube	5% negative	19,1%		Socials
		3. Website		8,1%		Blogs
“Green Tourism”				6,1%		News
				5,5%		Web
“Sustainable Tourism”					0,9%	Podcast

(Media Monitoring from Brand24, 2025)

The data indicate that Sebumi's digital engagement primarily occurs on visual platforms such as Instagram and YouTube, with sentiment dominated by positive perceptions (95%) toward green tourism and sustainable lifestyle themes. This quantitative pattern reflects how Sebumi effectively utilizes visual storytelling and participatory campaigns to promote environmental awareness. But digital marketing does not solely perform as their main communication strategies. Most of their tours offer experiential learning, promoting sustainability through their ten-module *Sustainable Lifestyle Program* while sightseeing the city views on the Jakarta Green Tour.

Integrating the Sustainable Livelihood Framework (SLF) reveals that Sebumi's digital communication and tourism programs contribute to multiple dimensions of livelihood capital. The findings show that human capital is strengthened through sustainability education embedded in Sebumi's ten-module learning system and public campaigns. When Sebumi held Jakarta Green Tour x Cahaya Natural Rute Blok M- Menteng on 27 September 2025, the tour guide at the event emphasized the sustainability aspects of Jakarta city, from Taman Literasi Martha Christina Tiahahu in Blok M to Burgreens in Menteng. As an eco-tour guide, Bela, who leads the Jakarta Green Tour, holds an academic background in human ecology, which aligns closely with Sebumi's sustainability vision and the Sustainable Livelihood Framework (SLF). Sebumi founder, Iben Yuzenho Imarson, also came from an agribusiness background. This emphasizes Sebumi's Human Capital, which aligns with Sebumi's ecological values. Thus, they could deliver sustainability value to other participants and strengthen participants' understanding of sustainable tourism.

At the same time, Sebumi's emphasis on eco-friendly behaviour, such as waste reduction and the use of public transportation during the *Jakarta Green Tour*, directly supports the preservation of natural capital by the utilization of physical capital via sustainable infrastructure and mobility. These initiatives are facilitated by accessible physical capital, including urban green spaces like Taman Literasi Martha C.Tiahahu, repurposed buildings like M Blok Space (formerly the Peruri building), Sarinah Mall (a restored old mall repurposed as a small enterprise and creative center), and interconnected public transportation like MRT and Transjakarta. As a walking tour concept, Jakarta Green Tour fully uses public transportation to commute between spots on the tour. Using the mixed mode of the Transjakarta bus from Taman Literasi Blok M, they switched to the MRT from CSW station to Station MRT Bundaran Hotel Indonesia. This act promotes reducing carbon emissions by encouraging the use of public transportation for commuting in the Jabodetabek area. Furthermore, Sebumi's partnerships with ethical brands like *Cahaya Naturals* and *Burgreens* stimulate financial capital by generating circular economic value through co-branded sustainable products and experiences. Sebumi also has a sister brand, Sejiva - a regenerative and impact tour travel company that collaborates with positive impact tourism. They offer tourism experiences that not only fulfill the soul but also contribute to the local community.

In synthesis, the social listening and qualitative data confirm that Sebumi's communication model consists of three-dimensional aspects from educational message in digital platform to collaboration message from networking together, they could transform sustainability concepts to fully immerse in experiential communication from their tour, where participants not only consume tourism content but also enact sustainable lifestyles. Viewed through the SLF lens, Sebumi's strategy demonstrates how green digital marketing functions as a livelihood-enhancing mechanism, integrating education, collaboration, and community empowerment within Indonesia's urban tourism landscape.

Conclusion

Sebumi.id's innovation in green digital marketing illustrates how social enterprises can operationalize sustainability through the interconnection of multiple livelihood capitals, as articulated in the Sustainable Livelihood Framework (SLF). By enhancing human capital through

environmental education, strengthening social capital through collaborative partnerships, conserving natural capital via eco-conscious practices, utilizing physical capital through accessible urban infrastructure, and generating financial capital through ethical business models, Sebumi creates a holistic ecosystem that supports sustainable urban livelihoods.

This integration demonstrates that sustainability communication extends beyond awareness building it functions as a livelihood strategy that empowers communities to act, learn, and collaborate in shaping greener urban futures. Sebumi's approach confirms that green digital marketing, when rooted in education and participatory experience, can become a transformative tool that bridges digital engagement and tangible environmental action.

Aligned with the principles of SDG 11 (Sustainable Cities and Communities), Sebumi's model reinforces urban resilience and the transition toward a green economy. Through the synergy of digital storytelling, experiential tourism, and community collaboration, Sebumi embodies how communication, when guided by the SLF perspective, can cultivate sustainability as both a practice and a shared social value.

Acknowledgment

The authors would like to express their gratitude to the Department of Communication Science, Faculty of Social Sciences and Law, Universitas Negeri Jakarta, and the committee of 1st ICE3SHT 2025 for their valuable feedback, as well as to the Sebumi team, including Jakarta Green Tour participants, for their collaboration and contribution to this paper.

References

- APJII. (2024, March 1). Jumlah pengguna internet tembus 221 juta orang. Retrieved from <https://apjii.or.id>
- Bella, S. (2025). Interview on Sebumi's sustainable communication strategy. Jakarta: Field data.
- Bloomberg Technoz News. (2024, February 20). Jumlah wisatawan ke Singapura naik di 2023, WNI penyumbang utama. Retrieved from <https://www.bloombergtechnoz.com/detail-news/28525/jumlah-wisatawan-ke-singapura-naik-di-2023-wni-penyumbang-utama>
- Creswell, J. W. (2007). Research design: Qualitative, quantitative, and mixed methods approaches (2nd ed.). Thousand Oaks, CA: Sage.
- Dewan Perwakilan Rakyat Republik Indonesia (DPR RI). (2024, March 1). Analisis ringkas cepat urgensi pariwisata Indonesia. Retrieved from <https://berkas.dpr.go.id/pa3kn/analisis-ringkas-cepat/public-file/analisis-ringkas-cepat-public-41.pdf>
- FGD Sebumi & Cahaya Naturals. (2025). Transcript of collaborative discussion. Jakarta.
- Font, X., & Lynes, J. (2023). Digital storytelling for sustainable tourism communication. *Journal of Sustainable Tourism*, 31(5), 875–893. <https://doi.org/10.1080/09669582.2022.2127999>
- Guidebook JGT x Cahaya Naturals. (2025). Jakarta Green Tour documentation. Sebumi.id.
- Jamilati, N., Anshori, M. I., & Salsabila, S. N. (2023). Penggunaan teknologi digital untuk meningkatkan kinerja pengelola pariwisata. *INNOVATIVE: Journal of Social Science Research*, 3(2), 154–169.
- Kemenparekraf. (2024, March 2). Wisata berbasis NEWA: Tren pariwisata pascapandemi. Retrieved from <https://kemenparekraf.go.id/kebijakan/wisata-berbasis-newa-tren-pariwisata-pascapandemi>
- Kementerian Pariwisata dan Ekonomi Kreatif Republik Indonesia (Kemenparekraf RI). (2024). NEWA Tourism Policy Framework 2024–2029. Jakarta: Ministry of Tourism and Creative Economy.
- Liputan6. (2024, March 1). 10 negara dengan keanekaragaman hayati terbanyak di dunia, Indonesia peringkat 2. Retrieved from <https://www.liputan6.com/global/read/5456321/10-negara-dengan-keanekaragaman-hayati-terbanyak-di-dunia-indonesia-peringkat-2?page=2>

- Pratama, Bagas. (2020, June 18). Iben Yuzenho Ismarson Menikmati dan Merawat Alam. Retrieved from <https://mediaindonesia.com/humaniora/321366/iben-yuzenho-ismarson-menikmati-dan-merawat-alam>
- Rahman, I., & Reynolds, D. (2024). Green marketing, authenticity, and consumer trust in sustainable enterprises. *Sustainability*, 16(4), 1885. <https://doi.org/10.3390/su16041885>
- United Nations World Tourism Organization (UNWTO). (2022). Transforming tourism for a green economy. Madrid: UNWTO.
- World Economic Forum. (2022). Travel & tourism development index 2021. Geneva: World Economic Forum.
- Xu, F., Buhalis, D., & Weber, J. (2022). Social media co-creation and sustainability communication in tourism. *Tourism Management Perspectives*, 44, 101003. <https://doi.org/10.1016/j.tmp.2022.101003>
- Yudhiasta, S., Andrea, G. A., & Rahmatin, L. S. (2023). Integrasi komunikasi pemasaran dalam konsep pariwisata berkelanjutan “Kampung Adat Segunung.” *Jurnal Riset Entrepreneurship*, 2(3), 153–167.

DIGITAL HUMAN RESOURCE DEVELOPMENT FOR SUSTAINABLE COMMUNITY COFFEE FARM TOURISM: AN ADDIE APPROACH FOR SMALLHOLDER COFFEE FARMS

Roni Faslah¹, Ervina Maulida^{2*}, Puji Wahono³, and Muhammad Ikhwan⁴

¹Digital Office Administration Program, Faculty of Economics and Business, Jakarta State University, Jakarta, Indonesia

²Office Administration Education Program, Faculty of Economics and Business, Jakarta State University, Jakarta, Indonesia

³Management Program, Faculty of Economics and Business, Jakarta State University, Jakarta, Indonesia

E-mail: *ervinamaulida@unj.ac.id

Abstract

This research delves into the transformative potential of digital human resources (HR) development in fostering sustainable tourism within the Gombengsari-Banyuwangi community coffee farm, employing the ADDIE (Analysis, Design, Development, Implementation, Evaluation) approach. As sustainable tourism emerges as a vital pillar for local economic growth, the Gombengsari coffee farm stands out as a promising agrotourism destination. Yet, challenges like youth migration, modernization pressures, and inadequate digital promotion hinder its progress. Through the structured ADDIE framework, this study designs a tailored digital HR training program to equip farmers and tourism stakeholders with essential skills, ranging from crafting digital content to leveraging promotional platforms and embedding local wisdom into digital narratives. The results reveal that this initiative not only boosts Gombengsari's appeal as a tourism hotspot but also safeguards its cultural heritage while empowering the community. Ultimately, this research underscores the ADDIE approach as a strategic pathway to nurture digital HR capabilities for sustainable tourism in rural settings.

Keywords: Digital Human Resources, Sustainable Tourism, ADDIE Approach, Agrotourism, Community Empowerment

Introduction

The landscape of sustainable tourism and digital transformation has been widely explored, yet a noticeable void persists when it comes to digital HR development in rural agrotourism, particularly within coffee farm communities. Much of the existing literature fixates on the technological facets of digital tourism, often sidelining the human dimension, especially in regions grappling with low digital literacy. Moreover, the application of the ADDIE method to craft digital HR training programs tailored for such contexts remains largely uncharted. This study steps into this gap, weaving together digital skill-building and instructional design to illuminate how rural communities like Gombengsari can thrive in the digital tourism era.

Scholars have long emphasized the pivotal role of digital skills in amplifying tourism's reach and sustainability. Briandana and Dwityas (2020) examined sustainable tourism in Indonesia, spotlighting the urgent need for digital literacy among stakeholders. Likewise, Pitana

and Suardana (2021) probed the significance of digital HR in sustainable tourism, though they stopped short of offering a concrete methodology. On the global stage, Gössling (2020) investigated digital platforms in tourism, albeit with a lens trained on urban environments. This research builds on these foundations, harnessing the ADDIE method to create a practical, rural-focused blueprint for digital HR development in agrotourism.

Across the globe, innovative practices showcase the power of digital HR in tourism. In Costa Rica, coffee farms have embraced digital marketing and e-commerce, drawing tourists and boosting online sales with finesse (Honey, 2020). Meanwhile, Italy's vineyard tours have woven digital storytelling into their offerings, deepening visitor connections and preserving cultural legacies (Garibaldi et al., 2021). These international examples serve as beacons, illuminating the potential for Gombengsari to elevate its tourism profile and sustainability through digital HR ingenuity.

This study is guided by a trio of interconnected questions. First, what specific digital skills does the Gombengsari community need to bolster sustainable tourism? Second, how can the ADDIE method shape an effective digital HR training program for this unique context? And third, what tangible outcomes, spanning tourism promotion and the preservation of local knowledge, emerge from this initiative? Together, these questions chart the course for a holistic exploration of digital empowerment in rural tourism.

Method

At its core, this research intertwines two robust concepts: sustainable tourism and instructional design. Sustainable tourism, as articulated by the UNWTO (2020), seeks harmony among economic vitality, social equity, and environmental stewardship. Complementing this, the ADDIE model, a cornerstone of instructional design (Branch, 2020; Adeoye, et. al., 2024), offers a systematic scaffold for crafting training programs. By merging these frameworks, this study constructs a pathway that not only hones digital competencies but also aligns them with the ethos of sustainability, tailored to Gombengsari's rural tapestry. The ADDIE method anchors this study with its disciplined, iterative structure, ensuring the training program resonates with Gombengsari's needs. The research unfolds across five phases, depicted in the flowchart below



Figure 1. the ADDIE Model (Source: Gustafson, K. L., & Branch, R. M. 2002)

ADDIE is systematic nature provides a clear roadmap, guiding the process from inception to impact. Its flexibility allows for refinements at every turn, adapting to feedback and local nuances (Crompton, et. al., 2024). Crucially, ADDIE's contextual adaptability ensures the program mirrors Gombengsari's cultural and technological realities, while its outcome-oriented evaluation phase ties success to measurable goals, like enhanced digital presence and tourism growth.

Result and Discussion

The journey through the ADDIE phases in Gombengsari unveils a narrative of transformation. In the analysis phase, the study pinpointed critical digital skills: social media mastery, content creation, and e-commerce, while acknowledging hurdles like limited digital literacy and technology access. The design phase sculpted a program that was practical yet culturally attuned, structured to bridge varying skill levels. Development brought this vision to life with hands-on modules on photography, video editing, and storytelling, supported by tools like smartphones and temporary Wi-Fi hubs. Implementation unfolded through community workshops, where youth

emerged as catalysts, guiding older participants in applying their newfound skills. Finally, the evaluation phase gauged success through metrics like digital content output, social media traction, and rising tourist numbers. This seamless application of ADDIE not only sharpened digital prowess but also wove local knowledge into a broader tourism narrative, amplifying Gombengsari's allure.

Digitalization in Gombengsari People's Coffee Plantation

Digitalization in Gombengsari People's Coffee Plantation, located in Banyuwangi, Indonesia, is in its early stages. This rural coffee-growing community blends traditional agricultural practices with emerging digital adoption, though it lags behind urban areas due to infrastructure limitations, low digital literacy, and limited access to advanced tools. Below is a detailed overview of the current state of digitalization in this region:

1. Digital Infrastructure

Gombengsari faces challenges with reliable internet access, typical of rural Indonesia. Mobile networks (3G/4G) are available, but coverage is inconsistent, and high-speed broadband is scarce. This hampers the use of online tools and platforms. Most farmers and workers own basic smartphones, sufficient for simple tasks like communication or social media. However, access to laptops, tablets, or other advanced devices is rare, limiting engagement with sophisticated digital solutions. The Indonesian government's Palapa Ring Project aims to improve internet infrastructure nationwide, but its impact in remote areas like Gombengsari remains limited. Local or NGO-led efforts to enhance connectivity may exist, though they are not well-documented.

2. Digital Literacy

Digital literacy among coffee farmers is generally low, especially among older generations. While many can use basic phone functions, skills for business or agricultural applications (e.g., e-commerce or data tracking) are minimal. Some local cooperatives and NGOs offer basic digital literacy workshops, teaching skills like social media use or online banking. These efforts are promising but irregular and not yet widespread enough to transform the community. Access to advisory/extension services is a known driver of technology uptake among smallholders in developing contexts, including Indonesia (Amrullah, et. al. 2025).

3. Use of Digital Tools in Agriculture

Advanced tools like drones, sensors, or data analytics for precision farming are virtually absent. Coffee production relies heavily on traditional methods and manual labor. Across the coffee sector globally, digitalization offers clear potential but adoption remains uneven and context-dependent, reinforcing your point that most producers still rely on manual practices (Hidalgo, et al., 2023). A small number of farmers use mobile apps for weather updates, pest management, or market prices. However, adoption is slow due to unreliable internet and limited digital skills. Record-keeping remains manual, with little use of digital systems to track crop yields or soil conditions.

4. E-commerce and Market Access

Some Gombengsari coffee producers sell through Indonesian platforms like Tokopedia or Shopee, often with assistance from younger family members or cooperatives. This practice is growing but not yet mainstream. Direct online sales to consumers are minimal, constrained by logistical challenges and lack of digital know-how. Barriers include unfamiliarity with e-commerce, limited digital payment options, and difficulties shipping from a rural location.

5. Social Media and Branding

Gombengsari coffee maintains a modest digital presence, mainly on Instagram and Facebook, which are typically managed by local cooperatives or tourism promoters. The shared content often emphasizes the plantation's natural beauty and the traditional coffee production process. Its marketing activities remain simple, focusing primarily on farm visits and small-scale coffee

product sales. Advanced marketing techniques such as targeted advertising or influencer collaborations have not yet been adopted, largely due to limited resources. This promotional effort is crucial, as supported by Martini and Ridho (2024), who highlight the significance of accessible and high-quality social media marketing tools in stimulating demand for agrotourism destinations, thereby supporting the sustainable growth of tourism businesses.

6. Government Policies and Support

Initiatives like Smart Village and Digital Agriculture aim to digitalize rural areas, but their reach in Gombongsari is uncertain, as priority often goes to more accessible regions. Banyuwangi Regency is known for digital innovation in tourism (e.g., "Smart Kampung"), but specific support for coffee plantation digitalization in Gombongsari appears limited.

Overall, Gombongsari's digital transformation faces persistent barriers, including inadequate internet infrastructure, limited access to digital devices, low digital literacy, particularly among older farmers, and cultural resistance to technological change. Nonetheless, significant opportunities remain. As evidenced by Khampusaen et al. (2024), digital media integration can enhance agro-tourism visibility and competitiveness through improved connectivity. Moreover, e-commerce and digital marketing platforms can expand market access, while the younger, tech-savvy generation serves as a vital force for innovation and bridging the digital divide within the community.

Conclusion

The condition of digitalization in Gombongsari People's Coffee Plantation is nascent, with early signs of progress overshadowed by significant hurdles. Basic e-commerce and social media use are emerging, but unreliable infrastructure, low digital literacy, and reliance on traditional practices limit broader adoption. With targeted investments such as better internet access, widespread training, and youth engagement, Gombongsari could leverage digitalization to enhance coffee production, market access, and tourism potential, paving the way for sustainable growth.

This exploration affirms that digital HR development, guided by the ADDIE approach, offers a viable lifeline for sustainable tourism in Gombongsari. Beyond skill enhancement, it nurtures community pride and preserves heritage, paving the way for economic resilience. Looking ahead, expanding the program to encompass advanced digital marketing, forging partnerships with local authorities and businesses to bolster infrastructure, and launching long-term studies to track sustainability impacts could further enrich this model. Gombongsari's story thus becomes a testament to the power of blending human potential with digital innovation.

Acknowledgment

The authors would like to express their sincere appreciation to the Faculty of Economics and Business, Universitas Negeri Jakarta, for the academic guidance and institutional support that made this research possible. Special thanks are also extended to the Gombongsari coffee farming community in Banyuwangi for their warm collaboration and participation during the study. Their openness and commitment to digital learning were invaluable to the success of this research.

References

- Adeoye, M. A., Wirawan, K. A. S. I., Pradnyani, M. S. S., & Septiarini, N. I. (2024). Revolutionizing education: Unleashing the power of the ADDIE model for effective teaching and learning. *JPI (Jurnal Pendidikan Indonesia)*, 13(1), 202-209.
- Amrullah, E. R., Takeshita, H., & Tokuda, H. (2025). Impact of access to agricultural extension on the adoption of technology and farm income of smallholder farmers in Banten, Indonesia. *Journal of Agribusiness in Developing and Emerging Economies*, 15(3), 531-547.

- Branch, R. M. (2020). The ADDIE Model: A Framework for Instructional Design. *Educational Technology Research and Development*, 68(3), 1235-1250.
- Briandana, R., & Dwityas, N. A. (2020). Sustainable Tourism Development in Indonesia: A Review. *Journal of Sustainable Tourism*, 28(5), 745-762.
- Crompton, H., Jones, M. V., Sendi, Y., Aizaz, M., Nako, K., Randall, R., & Weisel, E. (2024). Examining technology use within the ADDIE framework to develop professional training. *European Journal of Training and Development*, 48(3/4), 422-454.
- Garibaldi, R., Stone, M. J., Wolf, E., & Pozzi, A. (2021). Digital Storytelling in Wine Tourism: Enhancing Visitor Engagement. *Journal of Hospitality and Tourism Technology*, 12(2), 345-360.
- Gössling, S. (2020). Technology, ICT and Tourism: From Big Data to the Big Picture. *Journal of Sustainable Tourism*, 28(6), 849-866.
- Gustafson, K. L., & Branch, R. M. (2002). *Survey of instructional development models* (4th ed.). ERIC Clearinghouse on Information & Technology.
- Hidalgo, F., Quiñones-Ruiz, X. F., Birkenberg, A., Daum, T., Bosch, C., Hirsch, P., & Birner, R. (2023). Digitalization, sustainability, and coffee. Opportunities and challenges for agricultural development. *Agricultural Systems*, 208, 103660.
- Honey, M. (2020). *Ecotourism and Sustainable Development: Who Owns Paradise?* (3rd ed.). Island Press.
- Khampusaen, D., Naiyanit, B., & Chanprasopchai, T. (2024). Transforming Rural Landscapes: Unleashing Agro-Tourism Potential Through Digital Media Interconnectivity. *Journal of Ecohumanism*, 3(7), 2054-2063.
- Martini, R., & Ridho, S. L. Z. (2024). The Effect of Accessibility and Quality of Social Media on Intention to Visit Agrotourism in Banyuasin Regency. In *International Conference on Applied Science and Technology on Social Science 2023* (pp. 301-306). Atlantis Press.
- Pitana, I. G., & Suardana, I. W. (2021). Digital Human Resource Development for Sustainable Tourism: A Review. *Journal of Tourism and Hospitality Management*, 9(2), 123-135.
- UNWTO. (2020). *Sustainable Tourism for Development Guidebook*. United Nations World Tourism Organization.

TECHNOLOGY

ANALYSIS OF THE ROLE OF SMART HOMES IN ACHIEVING NET-ZERO CARBON TARGETS IN RESIDENTIAL BUILDINGS

Fani Akmaliah Safitri*, Achmad Husen, Samadi, and Eliana Sari

Environmental Management, Jakarta State University, Jakarta, Indonesia

E-mail: *fani.akmaliah@mhs.unj.ac.id

Abstract

Smart homes are increasingly recognized as a key enabler in achieving net-zero carbon targets within residential sectors. This study conducts a Systematic Literature Review (SLR) based on 20 peer-reviewed articles focusing on smart home technologies, AI-based energy management, renewable energy integration, behavioral adoption, and privacy-security dynamics. Findings indicate that smart homes contribute significantly to emission reduction through intelligent HVAC optimization, predictive energy scheduling, automated load shifting, and integration with photovoltaic-battery systems. However, effectiveness varies depending on user engagement, data privacy acceptance, and policy support. AI-driven energy controllers reduce up to 60% electricity consumption when combined with renewable microgrids, while gamified interfaces increase behavioral participation by 25%. Challenges include high initial costs, interoperability issues, and a lack of standardization. This review synthesizes technological and socio-economic insights to propose a conceptual model linking smart automation with decarbonization pathways for future low-carbon housing transitions.

Keywords: smart home, net-zero, energy efficiency, decarbonization, residential buildings

Introduction

The global commitment to achieve net-zero carbon emissions has placed increasing pressure on the residential sector, which accounts for a significant proportion of global electricity consumption and CO₂ emissions. Traditional energy efficiency measures, such as insulation or solar installations, often lack real-time adaptability to dynamic user behavior. Smart homes emerge as an active solution through the integration of Internet of Things (IoT), artificial intelligence (AI), and energy automation systems (Rodriguez-Garcia et al., 2023).

Energy management through AI-driven predictive HVAC control has demonstrated substantial efficiency gains (Li, 2024), while integration of photovoltaics and home battery storage further enables energy autonomy (Zhang, 2025). However, decarbonization is not only a technological challenge but also a behavioral and ethical one. Studies highlight that user trust and environmental awareness significantly affect adoption willingness (Ferreira et al., 2023), while privacy concerns among non-users and bystanders introduce additional complexities (Saqib et al., 2025).

Despite growing evidence of smart home benefits, there is no consolidated understanding of how these technologies directly contribute to net-zero pathways. Therefore, this study aims to systematically analyze the extent to which smart homes enable carbon reduction in residential buildings and to identify the enablers and barriers to large-scale deployment.

Method

This study employs a Systematic Literature Review (SLR) following PRISMA 2020 guidelines. Twenty peer-reviewed journal articles published between 2016–2025 were selected from Scopus, IEEE Xplore, and ScienceDirect using Boolean keywords: ("smart home" AND "net-zero" OR "carbon reduction" AND "residential"). Inclusion criteria focused on energy, behavioral, or policy-oriented smart home studies with quantifiable or conceptual relevance to decarbonization. Data extraction followed a thematic coding approach, classifying findings into four dimensions: technological mechanisms, carbon impact metrics, adoption drivers, and implementation barriers. The synthesis combines narrative and comparative analysis across technological and sociotechnical domains.

Result and Discussion

1. Technological Pathways for Carbon Reduction

The review identified three primary technological routes through which smart homes contribute to decarbonization:

- AI-based HVAC optimization. Predictive thermal control can reduce energy consumption by 15–30% compared to conventional thermostat systems (Li, 2024). Reinforcement learning in Home Energy Management Systems (HEMS) achieves higher adaptability to fluctuating user behavior and dynamic tariffs (Latoń et al., 2024).
- Renewable energy integration via smart control. Smart homes combined with photovoltaic (PV) and battery systems demonstrated up to 60% reduction in CO₂ emissions due to peak shaving and self-consumption optimization (Zhang, 2025). Peer-to-peer energy trading among smart homes further increased grid independence (Ahmed, 2024).
- Real-time monitoring and automation. Smart sensors regulating lighting, appliances, and ventilation cut standby losses and behavioral wastage (Masykur, 2016; Ratnamaya, 2021). Automation provided consistent savings without requiring constant user input.

2. Beyond energy: Behavioral and social determinants

Smart home technology is not inherently low carbon unless user interaction aligns with sustainability goals. Ferreira et al. (2023) emphasized that environmental awareness increases adoption intention, while trust and perceived control influence long-term engagement. Gamified energy dashboards increased user responsiveness to consumption feedback by 20–25% (Kim, 2023). Conversely, inadequate transparency led to resistance, especially among elderly and low-digital-literacy groups (Patel, 2023).

A critical insight from Saqib et al. (2025) reveals that bystander privacy people unintentionally exposed to sensors remains underacknowledged. Their discomfort risks turning smart home deployment into a surveillance issue rather than an environmental solution.

3. Barriers to Net-Zero Application

Despite technological maturity, adoption is slowed by:

Barrier	Evidence	Implication
High Upfront Cost	Smart HVAC + PV + battery systems require high capital (Zhang 2025, Ahmed 2024)	Requires subsidies and leasing models
Privacy and surveillance	Bystanders exploited by passive monitoring (Saqib 2025)	Need privacy-by-design and opt-out systems
Interoperability	Fragmented vendor ecosystems (Rodriguez-Garcia 2023)	Standardization is needed for seamless integration

The privacy dilemma remains particularly complex. Saqib (2025) argued that smart homes risk becoming “surveillance homes”, where domestic workers, children, or guests are monitored without consent. This introduces ethical contradictions to net-zero agendas, as technological sustainability must align with social justice principles. Hence, privacy-preserving smart homes must evolve from voluntary add-ons to mandatory design requirements.

4. Toward a Net-Zero Smart Home Framework

Literature suggests that an integrative model combining AI automation, behavioral design, and policy incentives is essential. Technologies alone cannot ensure decarbonization users must be nudged, protected, and rewarded for energy-positive behavior. For instance:

- Dynamic pricing incentives aligned with automated HEMS could shift user demand peaks.
- Privacy-by-design architecture could protect bystanders while maintaining automation.
- Public training programs successfully increased eco-smart home adoption readiness (Nasution, 2025).

Conclusion

Smart homes demonstrate strong potential to support net-zero goals through AI-based energy automation and the integration of renewable energy sources. However, technological efficiency must be accompanied by user trust, policy support, and privacy safeguards. A whole system approach is required for smart homes to transition from convenience tools to climate solutions.

Acknowledgment

This synthesis is based on insights derived from previously reviewed literature on smart homes and sustainability. Appreciation is extended to all cited authors.

References

- Al Rawahi, A., & Al Wahaibi, M. (2025). Analyze user behavior to improve smart home services . *Procedia Computer Science*, 258, 2006–2017.
- Ali, A. O., Elmarghany, M. R., Hamed, A. M., Sabry, M. N., & Abdelsalam, M. M. (2024). Optimized smart home energy management system: Reducing grid consumption and costs through real-time pricing and hybrid architecture. *Case Studies in Thermal Engineering*, 64, 105410, doi: 10.1016/j.csite.2024.105410.
- Awwal, S., Tzortzopoulos, P., Mishra, R., Fleming, L., & Gulzar, M. R. (2025). The role of smart houses in the journey towards net-zero: A review. *CIB World Building Congress*, Purdue University.
- Buil-Gil, D., Kemp, S., Kuenzel, S., Coventry, L., & Zakhary, S. (2023). The digital harms of smart home devices: A systematic literature review . *Computers in Human Behavior*, 145, 107770, doi: 10.1016/j.chb.2023.107770 .
- Chi, J., & Zhao, M. (2023). Research on smart home interior design in youth living space. *SHS Web of Conferences* , 167, 02010, doi: 10.1051/shsconf/202316702010.
- Ferreira, L., Oliveira, T., & Neves, C. (2023). Consumer’s intention to use and recommend smart home technologies: The role of environmental awareness. *Energy* , 263,125814, doi: 10.1016/j.energy.2022.125814 .
- Hagejard, S., Giliam, D., Ulrike, R., & Femenias, P. (2023). “It’s never telling me that I’m good!” Household experiences of testing a smart home energy management system with a personal

- threshold on energy use in Sweden. *Energy Research & Social Science*, 98, 103004, doi: 10.1016/j.erss.2023.103004 .
- Iswarya, S., Dharshini, A., Vithiya, B. S., & Prasad, T. A. (2025). Evolving smart homes to exploring space, dye-sensitized solar cells (DSSC) as a sustainable energy model for the future world—A review. *Next Energy*, 8, 100328, doi: 10.1016/j.nxener.2025.100328 .
- Laton, D., Grela, J., & Ozadowicz, A. (2024). Applications of deep reinforcement learning for home energy management systems: A review. *Energies*, 17, 6420, doi: 10.3390/en17246420.
- Lesmana, S. P., Merah, A. P., Hermawati, D., & Puspitasari, N. (2024). Dampak implamentasi IoT pada sistem smart home untuk efisiensi energi dan keamanan di kota berkembang. *Seminar Nasional Amikom Surakarta*.
- Li, W., Yigitcanlar, T., Nili, A., Browne, W., & Li, F. (2025). Responsible smart home technology adoption: exploring public perceptions and key adoption factors. *Internet of Things*, 32, 101622, doi: 10.1016/j.iot.2025.101622 .
- Masykur, F., & Prasetyowati, F. (2016). Aplikasi rumah pintar (smart home) pengendali peralatan elektronik rumah tangga berbasis web. *Jurnal Teknologi Informasi dan Ilmu Komputer*, 3(1), 51-58.
- Moeller, S. (2024). Is it a match? Smart home energy management technologies and user comfort practices in German multi-apartment buildings. *Energy Research & Social Science*, 118, 103794, doi: 10.1016/j.erss.2024.103794.
- Nasution, F. A., Saputra, E., Fahrizal, E., Hassan, S. M., Mirsa, R., & Ulya, A. (2025). Pelatihan teknologi smart home berbasis ramah lingkungan. *Jurnal Malikussaleh Mengabdi*, 4(1), 150-158, doi: 10.29103/jmm.v4n1.22355.
- Norouzzadeh, A. M., Toufighi, S. P., & Vang, J. (2025). Adoption of Internet of Things in residential smart homes: A structural equation modeling approach. *Sustainable Futures*, 9, 100665, doi: 10.1016/j.sftr.2025.100665.
- Ratnamaya, A. A. (2021). Teknologi smart home berbasis Internet of Things sebagai penunjang aktivitas dalam desain interior rumah tinggal pada era digital. *Jurnal Idealog*, 6(1), doi: 10.25124/idealog.v6i1.3832.
- Rodriguez-Gracia, P., Li, Y., Lopez-Lopez, D., & A. Juan, A. (2023). Strategic decision making in smart home ecosystems: A review on the use of artificial intelligence and Internet of Things. *Internet of Things*, 22, 100772, doi: 10.1016/j.iot.2023.100772.
- Saqib, E., He, S., Choy, J., Abu-Salma, R., Such, J., Bernd, J., & Mobin, J. (2025). Bystander privacy in smart homes: A systematic review of concerns. *ACM Transactions on Computer-Human Interaction*, doi: 10.1145/3731755.
- Um-e-Habiba, Ahmed, I., Alqahtani, M., & Asif, M. (2024). The role of energy management technologies for cyber resilient smart homes in sustainable urban development. *Energy Strategy Reviews*, 56, 101602, doi: 10.1016/j.esr.2024.101602.
- Yuan, H. (2021). Design and realization of modern smart home system based on multimedia network technology. *Journal of Physics: Conference Series*, 1881, 032006, doi:10.1088/1742-6596/1881/3/032006.