Korespondensi Artikel dengan judul "*Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals*" ke *Journal of Information Systems Engineering and Management*

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Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals

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Abstract

Beach erosion in Subang Regency poses growing environmental and socioeconomic challenges. The study area focuses on the coastal region of Subang Regency, specifically the four sub-districts: Blanakan, Sukasari, Legonkulon, and Pusakanagara. This article explores innovative mitigation approaches to address this problem, focusing on solutions aligned with the Sustainable Development Goals (SDGs). Strategies such as wave breaker stabilization and community-led restoration projects are evaluated for their effectiveness in improving coastal protection, biodiversity, and livelihoods of local communities. By integrating modern technology with ecological conservation, this innovation provides a sustainable framework for long-term coastal resilience and sustainable development in Subang Regency.

Keywords: coastal erosion, coastal protection, innovative mitigation, sustainable development goals

1. Introduction

Coastal erosion is a pressing environmental challenge that threatens the sustainability and resilience of coastal communities worldwide, including those in Subang Regency, Indonesia. This issue has significant implications for socio-economic development, as it can undermine crucial infrastructure, disrupt essential industries, and displace vulnerable populations (Rakhmanissazly et al., 2018). To address this issue and meet the Sustainable Development Goals, innovative approaches to coastal erosion mitigation are urgently needed (Drestalita et al., 2021) (Salim et al., 2024).

Subang regency, found on the north coast of Java, Indonesia, has experienced significant coastal erosion in recent decades because of a complex interplay of natural and human factors. River

development and other infrastructure projects have often worsened the issue by disrupting natural sediment transport and wave dynamics along the coast. Furthermore, the region's sensitivity to monsoon-induced oceanographic processes has accelerated coastal erosion (Ariffin et al., 2019).

The coast of Subang Regency, West Java has Subang Regency's coastal area is approximately 333.57 km2, accounting for roughly 16% of its total area. Mangrove forests along Subang Regency's coast have the potential to be converted into cultivation businesses. The coast of Subang Regency is divided into four sub-districts: Blanakan, Sukasari, Legonkulon, and Pusakanagara (BPS-Statistics Subang Regency, 2024). The river basins flow into Subang Regency's coast, including the Cilamaya, Blanakan, Ciasem, and Cipunagara. Subang Regency's coastline is changing primarily due to sedimentation and abrasion.

Coastal erosion in Subang Regency affects environmental and economic stability by endangering ecosystems and disrupting local livelihoods. As shorelines retreat, habitats like mangroves disappear, reducing biodiversity and natural storm protection. This has an impact on fisheries, tourism, and agriculture, all of which are important to the local economy. Furthermore, erosion can damage infrastructure, making residents more vulnerable. Addressing coastal erosion is critical to ensuring the health of ecosystems and local communities, as well as supporting the region's sustainable development efforts.

The interaction between natural forces—like wave action, tides, and sea-level rise—and human activities such as coastal development, deforestation, and unsustainable fishing practices has intensified shoreline degradation in Subang Regency. Natural erosion processes are accelerated by the removal of protective vegetation and the alteration of coastal landscapes. This needs innovative solutions, such as ecosystem restoration and engineered barriers, to mitigate erosion's impacts (Anu et al., 2024). Effective strategies can help balance human needs with environmental conservation (Barbier, 2016), ensuring long-term resilience for coastal communities.

This paper examines the strategies for coastal erosion mitigation involves implementing solutions that not only address the immediate risks posed by shoreline degradation but also align with the Sustainable Development Goals (SDGs) (UNESCO, 2018). For example, restoring mangrove forests can stabilize coastlines while enhancing biodiversity (SDG 14) and supporting local fisheries, thus improving community livelihoods (SDG 1 and SDG 11). Additionally, incorporating eco-engineering practices, such as building hybrid structures, can mitigate erosion while promoting climate resilience (SDG 13). This multifaceted approach ensures long-term environmental health and socio-economic stability for coastal communities.

Integrating ecological conservation with technological advancements aims to create a comprehensive approach to coastal management (Solihuddin et al., 2021) (UNFCCC and IUCN, 2022). This involves using innovative techniques, like eco-engineered structures and sustainable practices, to bolster natural defenses against erosion while enhancing ecosystem health (UNFCCC and IUCN, 2022). By fostering resilience, these methods prepare communities for climate impacts, promote sustainable development through responsible resource management, and improve community well-being by ensuring economic stability and environmental quality (United Nations Environment Programme, 2023). This comprehensive strategy addresses ongoing coastal challenges while aligning with broader goals of sustainability and community empowerment.

2. Materials and Methods

2.1. Study Area

Subang Regency (Indonesian: Kabupaten Subang) is a regency (kabupaten) in West Java, Indonesia. The Regency is bordered by the Java Sea to the north, Indramayu Regency to the east, Sumedang Regency to the southeast, West Bandung Regency to the south, and Purwakarta and Karawang Regencies to the west. The total area of Subang Regency is 2.165.55 km^2. Astronomically, Subang Regency is found at 107°30'49"-107°54'0" east longitude and 6°10'59" - 6°48'59" south latitude (BPS-Statistics Subang Regency, 2024).

The study area focuses on the coastal region of Subang Regency, specifically the four sub-districts: Blanakan, Sukasari, Legonkulon, and Pusakanagara. Figure 1 shows the coastal region in Subang Regency. Blanakan spans 103.13 km^2 with an elevation of 5 meters above sea level (masl), Sukasari covers 59.65 km^2 at 2 masl, Legonkulon is 64.02 km^2 at 3 masl, and Pusakanagara occupies 59.52 km^2 at 9 masl (BPS-Statistics Subang Regency, 2024). These areas differ in terms of size and elevation, with Sukasari (2 masl) and Legonkulon (3 masl) being the lowest, making them more susceptible to coastal erosion and flooding. The mean wave heights are 0.43–0.57m along the coast of Subang Regency. The region's proximity to the sea, combined with varying altitudes, presents unique environmental challenges, needing effective coastal zone management and erosion mitigation strategies to ensure the sustainability of the coastal communities.

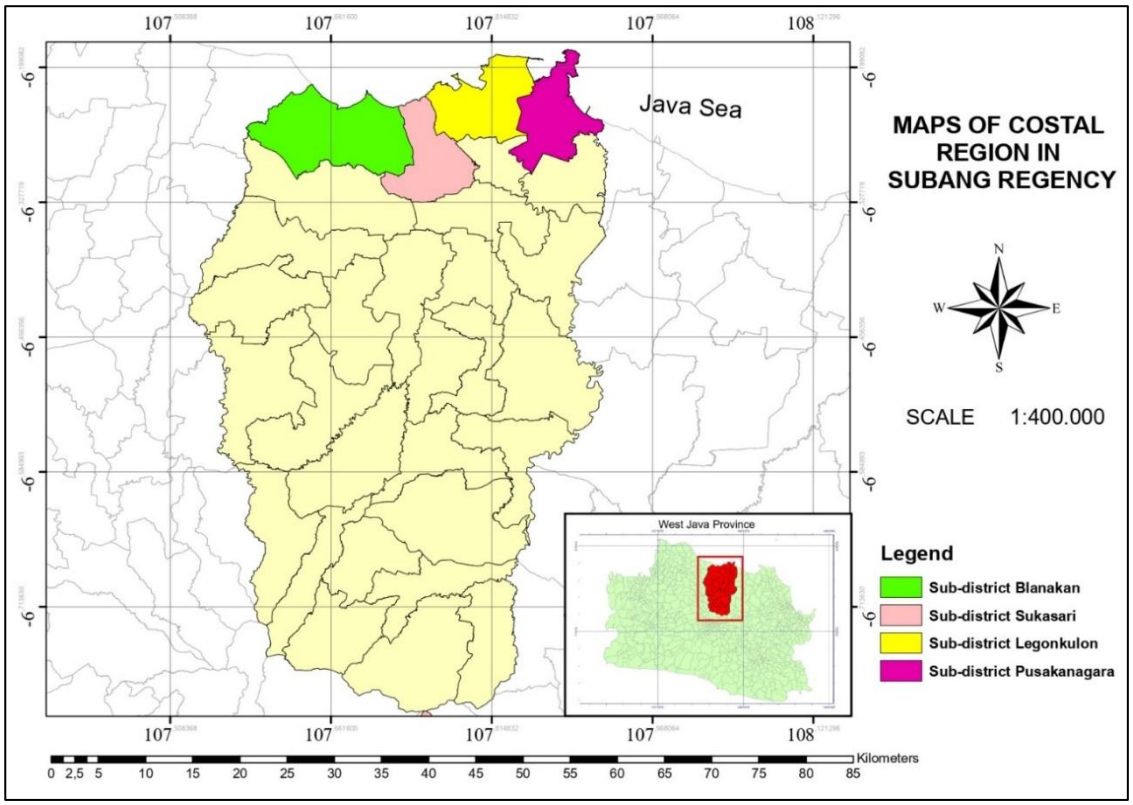

Figure 1 Maps of Coastal Region in Subang Regency

In Subang Regency, several villages have been affected by natural disasters in recent years. Flooding occurred in the Sukasari sub-district (1 village), Legonkulon sub-district (3 villages), and Blanakan sub-district (1 village) in 2021; in the Legonkulon sub-district (5 villages) in 2022; and in the Pusakanagara sub-district (1 village) in 2023. Additionally, a landslide occurred in the Legonkulon sub-district (1 village) in 2022 (BPS-Statistics Subang Regency, 2024).This data highlights the vulnerability of certain sub-districts, particularly Legonkulon, to recurring natural disasters like floods and landslides, underscoring the need for effective disaster management and mitigation strategies in these areas.

The land subsidence in Subang Coast is in a range between 0 to 5 cm/year, and most of the village's area has less than 1 mm/year. The villages are from Cilamaya Girang (in the western part of Subang Coast) to Legon Wetan (in the eastern part of Subang Coast). Except these villages, the land subsidence in Pangarengan and Patimban Villages at Sub-district Pusakanagara are more than 4 mm/year (Handiani et al., 2022).

2.2. Data Collection using Advanced Geospatial Technology

a. Google Earth Pro serves as a powerful tool for monitoring and mapping coastlines, utilizing high-resolution satellite and aerial imagery to detect changes such as erosion, sediment deposition,

and coastal development. A key feature is its access to historical imagery, enabling users to track coastline and land use changes over time. This capability offers valuable insights into long-term trends, including track coastline changes over time. This historical data provides a clear visual understanding of how the coastline in Subang Regency has receded or shifted due to erosion, helping identify the most vulnerable areas. Furthermore, Google Earth Pro can be integrated with Geographic Information System (GIS) data, enhancing its utility for detailed geospatial analysis. Figure 2 shows the sub-district of Legonkulon at three different time points: 2003, 2013, and 2023.

(a) Legonkulon subs-district in 2003

(b) Legonkulon subs-district in 2013

(c) Sub-district Legonkulon in 2023

Figure 2 Aerial Mapping of Legonkulon Sub-district in (a) 2003, (b) 2013, and (c) 2023 (Source: Google Earth Pro)

b. The Geospatial Information Agency, Indonesia (BIG) plays a pivotal role in sustainable coastal management by providing high-quality geospatial data. This data is essential for tracking coastline changes caused by erosion, sedimentation, or sea-level rise, and helps identify vulnerable areas requiring interventions like coastal protection or restoration. Accurate maps from BIG also allow for effective monitoring of land use changes in coastal zones, such as urban expansion and deforestation. This supports the development of sustainable land use policies that protect ecosystems and ensure responsible development. Additionally, BIG's data integration with GIS (Geographic Information System) enhances its utility for detailed geospatial analysis, crucial for coastal management and planning (A Madinu et al., 2024).

   The villages in eastern part of Subang have relief contour between 0 and 5m and this value occurs in western villages, from Muara to Jayamukti villages, while the Cilamaya Girang and Rawameneng at Sub-district Blanakan is larger than 5m and less than 10 m. This means the coast has a substantial risk of inundation.

   In this study, tidal range at Subang Regency is in a range between 1 and 1.2 m, hence it is characterized as micro-tidal area (<2 m). These tidal records were derived from several predicted locations along the coast while the tidal prediction is estimated from the Geospatial Information Agency, Indonesia.

c. ArcGIS offers the advantages for coastal and land use mapping, including advanced spatial analysis and real-time data integration. Its ability to manage complex datasets, model future scenarios, and promote collaboration makes it an essential tool for coastal managers, researchers, and policymakers focused on sustainable coastal development and environmental protection. Figure 3 shows the land use of the sub-districts Blanakan, Sukasari, Legonkulon, and

Pusakanagara in 2023, highlighting the integration of data from the Indonesian Geospatial Information Agency (BIG) and ArcGIS.

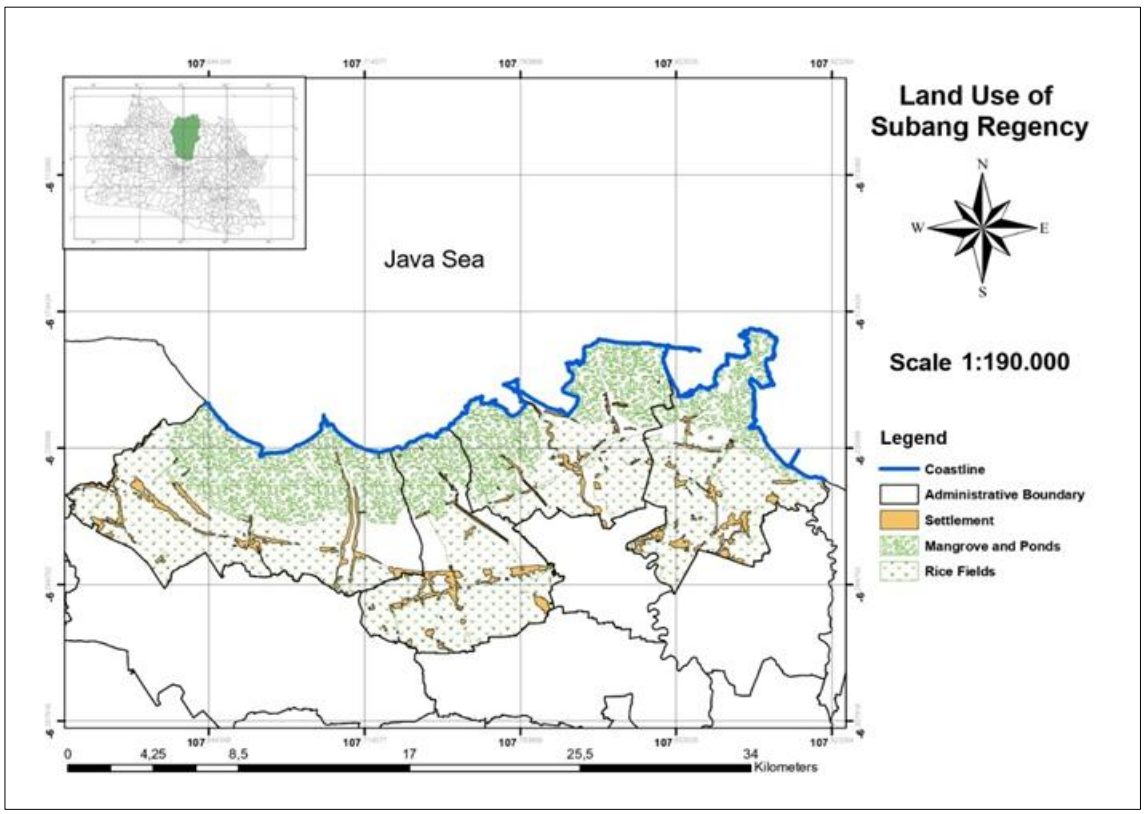

Figure 3 Land-use of sub-district Blanakan, Sukasari, Legonkulon, and Pusakanagara at Subang Regency in 2023

The northern coast of Java plays a vital role in economic development due to its strategic use across multiple sectors. It supports seaports, marine tourism, power plants, fisheries, agriculture, industrial zones, public services, and government offices, among other activities. This diverse usage underlines the region's importance in contributing to economic growth and infrastructure, positioning it as a critical area for both national and regional development initiatives (Solihuddin et al., 2021). Satellite data from Google Earth provides insight into the current landscape of Subang Regency's coastal areas. Tegalurung in Sub-district Legonkulon and Anggasari in Sub-district Sukasari are notable for their intensive fishponds, while Patimban in Sub-district Pusakanagara hosts both urban and industrial zones. Blanakan and Tanjungtiga in Sub-district Blanakan feature coastal sandy areas, and Legonkulon and Mayangan in Sub-district Legonkulon are predominantly urban. This variety of land uses underscores the region's mixed-use nature, balancing agricultural, industrial, and urban development along the coast.

d. Drones have revolutionized coastal management by offering superior monitoring and mapping capabilities, especially in difficult-to-access environments. They provide highly detailed and up-to-date imagery, which is invaluable for tracking coastal changes like erosion, sediment deposition, and vegetation growth. This high level of accuracy is often unachievable with traditional methods. Drones can also navigate challenging terrains, such as swamps, mangroves, and remote islands, allowing access to areas ground teams cannot reach. Their ability to quickly collect data over large areas with high temporal resolution is crucial for long-term coastal monitoring and supports adaptive management strategies. Figures 4-7 illustrate coastal conditions in the subdistricts of Blanakan, Sukasari, Legonkulon, and Pusakanagara, captured by drone in September 2024.

Figure 4 Mangrove and Ponds at Ciasem Bay, Sub-district Blanakan in September 2024

Figure 5 Mangrove at Sub-district Sukasari in September 2024

Figure 6 Pondok Bali at Sub-district Legonkulon in September 2024

Figure 7 Port of Patimban at Sub-district Pusakanagara in September 2024

2.3. Monitoring and Evaluation

Erosion rate measurement combines satellite imagery (Google Earth Pro) and on-ground measurements, such as GPS tracking with drones and physical surveys, to evaluate shoreline changes over time. Satellite imagery allows for large-scale monitoring of shoreline dynamics, while on-ground data provides precise erosion rate measurements. This integrated approach enables researchers to accurately assess coastal erosion, show trends, and support effective management strategies aimed at mitigating degradation and enhancing coastal resilience. In Subang Regency, West Java, natural factors like erosion, sedimentation, and rising sea levels are influencing shoreline changes. Monitoring these processes is essential for informed coastal management and planning. Remote sensing, especially through satellite imagery, is a valuable tool for continuous, large-scale observation of shoreline dynamics. The study of shoreline changes in this region is vital for guiding sustainable management and future planning. Figures 8-11 show the integration of coastline data from 2003, 2013, and 2023 using Google Earth Pro and ArcGIS for sub-districts Blanakan, Sukasari, Legonkulon, and Pusakanagara.

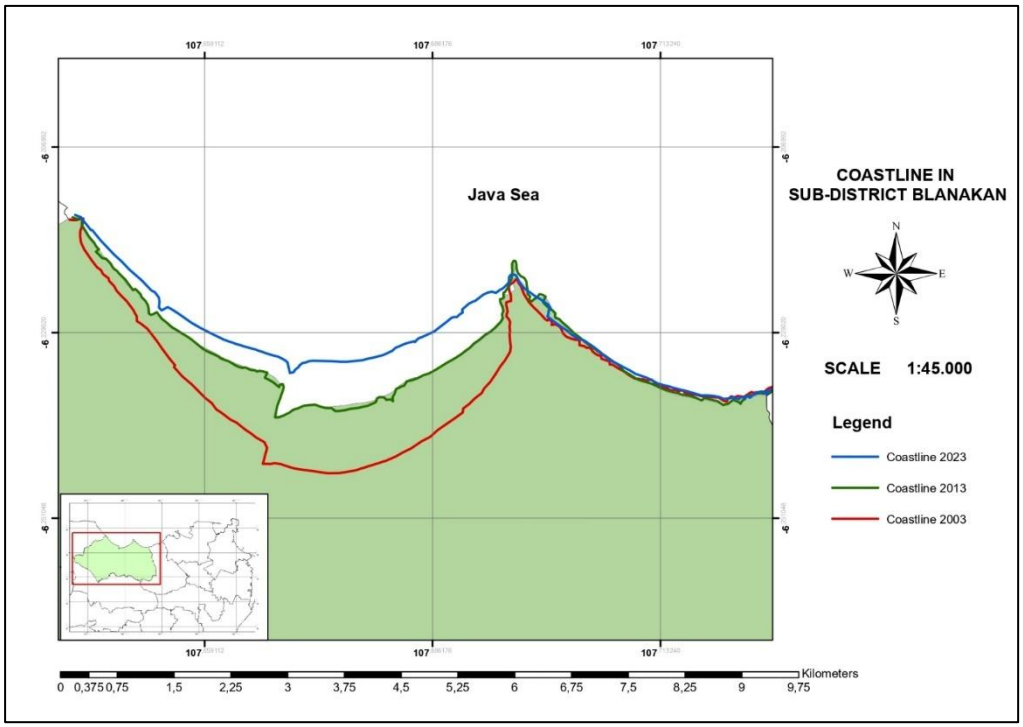

Figure 8 Coastline change at Sub-district Blanakan in 2003, 2013 and 2023

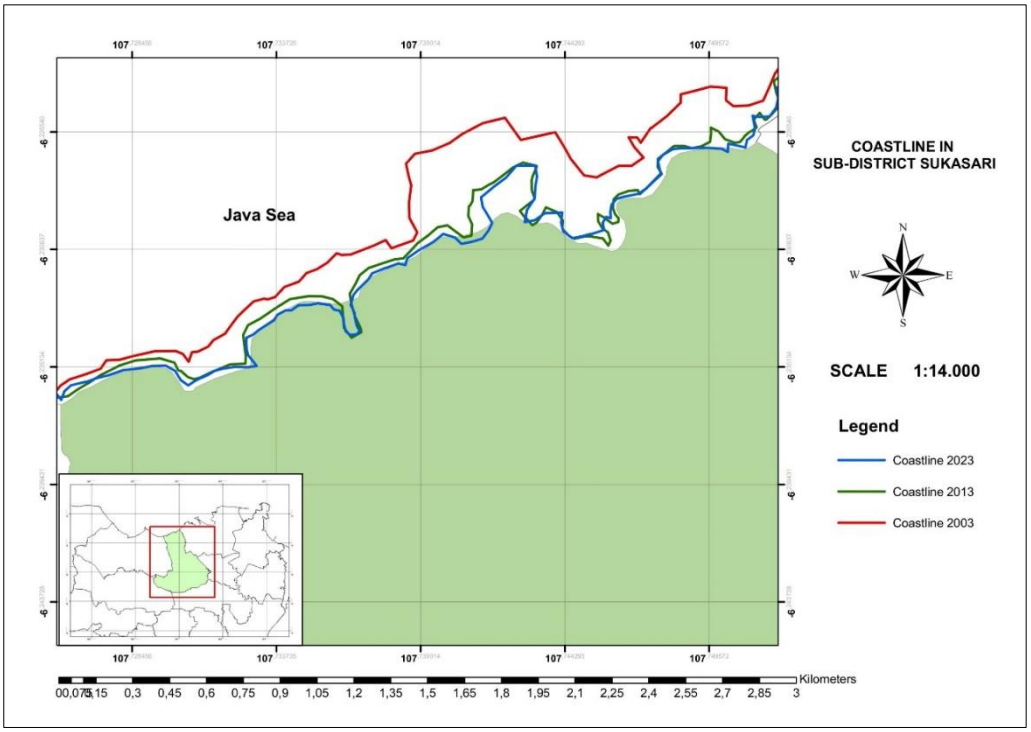

Figure 9 Coastline change at Sub-district Sukasari in 2003, 2013 and 2023

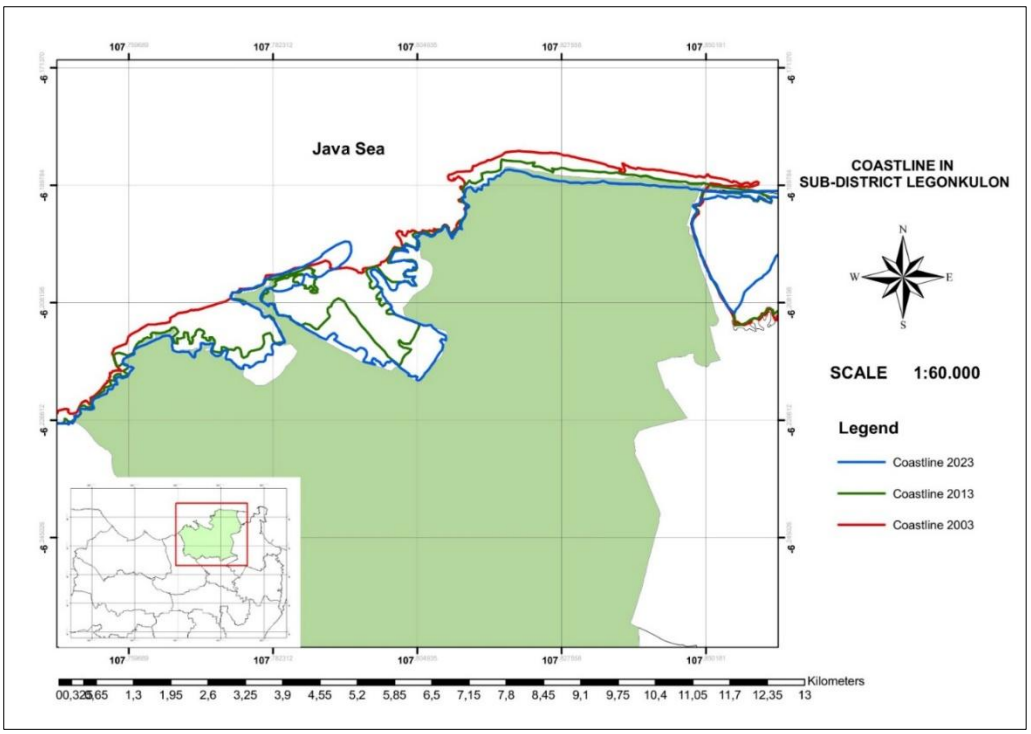

Figure 10 Coastline change at Sub-district Legonkulon in 2003, 2013 and 2023

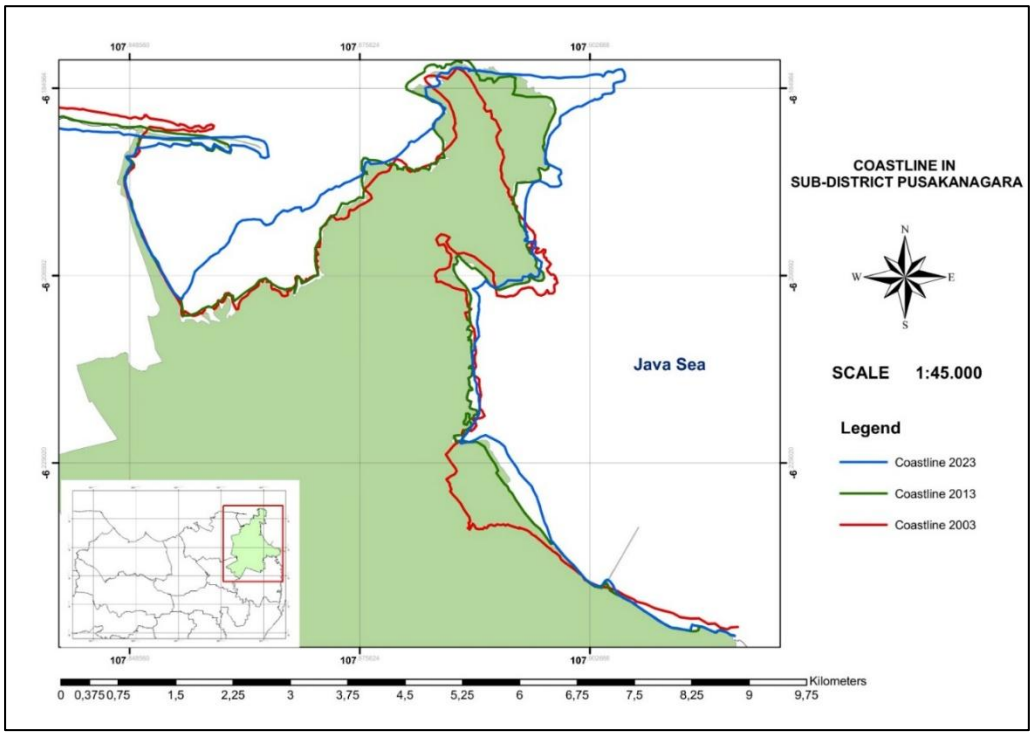

Figure 11 Coastline change at Sub-district Pusakanagara in 2003, 2013, and 2023

The results of the analysis of changes in the coastline of Subang Regency during the periods 2003, 2013, and 2023 were obtained from Google Earth Pro satellite image data. Data taken every decade is marked with a red line to depict the 2003 coastline, a green line to depict the 2013 coastline, and a blue line to depict the coast in 2023 (Figure 8-11). The results show that changes in the coastline occurred in the form of accretion in Sub-district Blanakan and Sub-district Pusakanagara, as well as erosion in Sub-district Legonkulon. The leading cause of coastline changes is the use of coastal areas to support community economic activities, resulting in erosion, accretion, sea water intrusion, reduction of mangrove forests and damage to coral reefs (Kalther & Itaya, 2020). Land accretion that forms on the coast of Subang, especially in the Blanakan District, is caused by excess sediment runoff from the Ciasem River, which is then pushed by river flows towards the west (Nandi, 2014). Changes in coastal waters are also influenced by the dynamic interactions between water input from the sea and freshwater from rivers (Nandi et al., 2016).

3. Results and Discussions

This study highlights the natural processes of accretion and erosion along Subang Regency's coast from 2003 to 2023 (Figures 8-11), with accretion occurring primarily in the eastern and western coastal areas, while central parts experience erosion. Accretion is mainly driven by sediment deposition from the Ciasem River, which is transported westward by longshore currents and settles

in Blanakan Bay due to the area's sloped coast. Additionally, sediment from the Cipunagara River also contributes significantly. Changes in land use, such as the establishment of fishponds and enhancements in mangrove vegetation and silvofishery practices, have supported accretion. Despite efforts by local organizations to plant mangroves, the initiatives faced challenges due to limited monitoring. This dynamic between natural processes and land use changes offers valuable insights into effective coastal management.

Coastal erosion poses a significant threat to communities, ecosystems, and infrastructure in Subang Regency, where the dynamic forces of waves, tides, and human activities accelerate shoreline degradation. Erosion occurred in the locations on the north coast of Subang Regency and was concentrated in the main area of Sub-district Legonkulon (Figure 10). Google Earth Pro satellite imagery has shown erosion from 2003 to now. This event was caused by the intensive opening of pond areas, which eroded the mangrove area (Figure 2). In 2003, fishponds dominated the study area as a key economic resource for local communities. However, erosion has intensified due to the removal of natural protective barriers like mangrove forests. These mangroves, historically essential for buffering wave action and storm surges, have declined significantly due to unsustainable land conversion practices. This shift began in the 1970s with the expansion of fish and shrimp ponds, which accelerated throughout the 1990s (Kalther & Itaya, 2020). The loss of mangroves has therefore left the coastline more vulnerable to erosion, highlighting the need for sustainable land management and mangrove restoration to protect the area's ecological and economic resilience.

Field inspections revealed areas of significant inland-reaching erosion along the coast and submerged the pond areas (Figure 2). The coastal area of Sub-district Legonkulon has a high population density, reflecting its concentration of economic activities such as crop production and fisheries. This demographic and economic concentration highlights the area's importance in supporting local livelihoods and underscores the need for sustainable coastal management practices to support its communities. (Kalther & Itaya, 2020). A 2023 report showed that 30.03% of Subang's Gross Regional Domestic Product (GRDP) was derived from the agricultural, forestry, and fisheries sectors, reflecting a slight decline from 30.15% in 2022. This shift suggests minor changes in economic contributions from these sectors, potentially showing adjustments in resource allocation or productivity within Subang's regional economy (BPS-Statistics of Subang Regency, 2024). Erosion leads to ongoing coastal disasters that significantly affect coastal communities, emphasizing the need for targeted rehabilitation efforts. Restoring coastal areas, particularly through mangrove revegetation along the shoreline, can reduce the impact of marine disasters by stabilizing the coastline and providing a natural buffer against waves and storm surges. This approach is essential for enhancing resilience in

coastal communities and safeguarding their livelihoods against the effects of erosion and other marine-related threats. (Indarsih & Masruri, 2019) (Menéndez et al., 2020).

In addition to mangrove restoration, reducing the extent of fishponds in designated rehabilitation zones is essential for effective coastal management. Mangrove ecosystems offer a sustainable, nature-based solution to coastal erosion by naturally stabilizing shorelines and mitigating erosion. This approach supports Sustainable Development Goals (SDGs) related to environmental protection, climate resilience, and sustainable ecosystems. These findings emphasize the importance of conserving and restoring mangroves as a long-term strategy for managing coastal areas and preserving local ecosystems.

4. Conclusions

Innovative approaches to coastal erosion mitigation in Subang Regency, such as hybrid mangrove-wave breaker systems, have proven effective in reducing erosion rates and enhancing biodiversity. These strategies not only address environmental challenges but also foster community engagement and socio-economic benefits, aligning with the Sustainable Development Goals. The successful integration of these techniques suggests a practical path toward sustainable coastal management, highlighting the importance of continued research and investment in innovative solutions for long-term resilience in coastal communities.

Mangrove ecosystems in Subang Regency have proven to be an effective and sustainable solution for mitigating coastal erosion, aligning with the Sustainable Development Goals (SDGs). The natural ability of mangroves to stabilize shorelines, reduce wave energy, and enhance biodiversity highlights their critical role in protecting coastal areas from degradation. The success of these efforts depends on continuous restoration, community engagement, and innovative approaches to mangrove management. By integrating mangrove rehabilitation into coastal development plans, long-term environmental and socio-economic resilience can be achieved, ensuring sustainable coastal management for future generations.

Addressing coastal erosion in Subang Regency requires a comprehensive, multi-faceted approach that blends innovative, nature-based solutions with community involvement and ability building. This strategy includes restoring mangrove ecosystems and integrating hybrid solutions like eco-engineered structures to reduce wave energy and stabilize shorelines. Simultaneously, community engagement is essential, where locals take part in monitoring, maintenance, and conservation activities. This fosters a sense of ownership, ensuring the long-term sustainability of efforts. Combining ecological

restoration with community-driven practices creates a resilient framework for mitigating coastal erosion and promoting sustainable development.

By adopting an Integrated Coastal Zone Management (ICZM) framework, Subang Regency can tackle coastal erosion through a balanced approach that integrates environmental, social, and economic factors. This framework promotes coordinated efforts among stakeholders, combining nature-based solutions, such as mangrove restoration, with sustainable development strategies like eco-tourism and community-based conservation. The ICZM fosters collaboration across governmental agencies, local communities, and industries, ensuring that erosion mitigation efforts align with Sustainable Development Goals (SDGs), particularly in promoting climate resilience (SDG 13) and conserving marine ecosystems (SDG 14). This comprehensive approach secures the long-term sustainability of coastal communities.

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Sun 15/12/2025 8:36 AM

Olga Pattipawaej:

Thankyou for submitting the manuscript, "Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals" to Journal of Information Systems Engineering and Management with the online journal management system. You will be able to track its progress through the editorial process by logging in to the journal web site.

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

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Artikel dalam proses reviu (10 Januari 2025)

Pada tanggal 10 Januari 2025 diperoleh Informasi bahwa artikel dalam proses reviu.

Process reviewed

Participants

JISEM Chief-in-editor

Olga Pattipawaej

Messages

Note	From
Dear Author Your article is now in the process of being reviewed. You will receive further information shortly. Yours sincerely JISEM Chief-in-editor	editor 2025-1-10 01:39 PM

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Hasil reviu (5 Februari 2025)

Hasil reviu dari 2 *reviewer* telah dikirim via email pada tanggal 5 Februari 2025.

Review Report

EJ

Editor JISEM<editor@jisem-journal.com>

To: Olga Pattipawaej

Reply Reply all Forward

Wed 2/5/2025 8:36 AM

Olga Pattipawaej:

The reviewers have submitted their review reports. You should now be prepared to address any requests for revisions to your manuscript.

Chief-in-Editor
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Independent Review Report, Reviewer 1
EVALUATION
Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation.
There are still some parts that need to be improved from the manuscript.
1. The title, with its focus on "Innovative Approaches," is excellent but sets a high bar for the paper. The manuscript must thoroughly detail techniques that are genuinely new, significantly different from traditional

methods, or represent a novel combination/application specifically relevant to the ecological and socio-economic context of Subang.

2. The abstract describes a timely and important study that aligns with global priorities (e.g., coastal resilience and SDGs). Overall Rating: Acceptable with minor revisions. The abstract needs a brief mention of the methodology and a key finding. The full paper should be checked to ensure the promised evaluation and integration of modern technology are fully detailed and supported by data.

3. The introduction is strong: it effectively establishes the importance of coastal erosion, zeroes in on the problem in Subang Regency, Indonesia, and introduces the necessity of innovative, SDG-aligned mitigation strategies. The ideas flow logically from the global issue to the local context and then to the proposed solutions.

4. This text effectively combines the Study Area Description and the start of the Materials and Methods, but it needs significant restructuring and refinement to meet clear scientific publication standards.

5. The discussion is strong, offering a comprehensive and well-supported argument about the dual nature of coastal change in Subang Regency. To boost clarity and practical significance, you should: strengthen the links explaining the longshore drift direction, clarify the specific role of land use in the observed accretion, and make the interpretation of the GRDP data (Gross Regional Domestic Product) more explicit.

6. The conclusions are excellent. They smoothly transition from presenting results to offering forward-looking recommendations based on proven strategies (hybrid systems, mangroves) and policy frameworks (ICZM - Integrated Coastal Zone Management). By repeatedly emphasizing community engagement and the Sustainable Development Goals (SDGs), the findings are effectively placed within a broader, globally relevant context.

****

Independent Review Report, Reviewer 2

EVALUATION

Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation.

A comment and few recommendations are needed to improve the quality of the manuscript.

1. To maximize the title's impact and clearly define the paper's significance, I strongly recommend adding a phrase that highlights the goal or impact of the innovation. This will give the title a broader policy or sustainability angle.
2. This abstract is effective: it clearly identifies the major local problem (beach erosion in Subang Regency) and states its purpose—to explore innovative mitigation approaches that align with the Sustainable Development Goals (SDGs). It also successfully outlines the study area and mentions the key strategies being used.
3. The introduction includes all the necessary elements but requires significant editing for conciseness, clarity, and flow. Most critically, the author must add a clear, explicit statement of the paper's objective and/or research question at the end. This is essential for effectively guiding the reader into the body of the paper.
4. The document requires reorganization. You must clearly separate the Descriptive/Contextual information (Study Area) from the Methodological/Procedural steps (Materials and Methods). Additionally, several paragraphs contain premature Results and Discussion content that should be moved.
5. This "Results and Discussions" section is well-structured and informative. It effectively connects natural processes (accretion and erosion) with human factors (like land-use change, especially fishponds and mangrove removal). The discussion successfully identifies the main drivers: accretion: river sediment and longshore drift and erosion: mangrove removal for fishponds. Crucially, the section successfully links these physical processes to their socio-economic impacts (threats to communities and the GRDP contribution). However, a few areas should be strengthened to improve clarity and overall impact.
6. The conclusions are highly effective. They successfully translated the study's data on accretion and erosion drivers into a robust policy roadmap, making them a valuable contribution to regional coastal management efforts. They only need minor editing to integrate more tightly with the specific results and strengthen the claims regarding the hybrid systems.

Tanggapan terhadap hasil reviu (10 Februari 2025)

Penulis memberikan tanggapan terhadap hasil reviu dari 2 *reviewer* disertai dengan perbaikan artikel sesuai dengan tanggapan dari *reviewer* pada tanggal 10 Februari 2025.

Response to the Review Reports

Olga Pattipawaej

To: Editor JISEM <editor@jisem-journal.com>

Reply Reply all Forward

Mon 2/10/2025 7:40 AM

Revised Paper JISEM

Dear Editor,
Regarding my manuscript, "Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals," I appreciate your correspondence and forwarding the insightful comments and recommendations from Reviewers 1 and 2.

I have carefully considered and addressed every point raised in the reviews and have thoroughly revised the manuscript accordingly. The revisions, detailed in the accompanying point-by-point response, have significantly enhanced the clarity, structure, and scientific rigor of the submission.

I believe these changes make the manuscript substantially stronger and more appropriate for publication in your esteemed journal.

I appreciate your time and consideration and look forward to your decision.

Sincerely,
Olga Pattipawaej

****

Response to the comment from Reviewer 1

1. The title, with its focus on "Innovative Approaches," is excellent but sets a high bar for the paper. The manuscript must thoroughly detail techniques that are genuinely new, significantly different from traditional methods, or represent a novel combination/application specifically relevant to the ecological and socio-economic context of Subang.
   Response from the authors:
   The paper will fully address the high expectations set by the term "Innovative Approaches" by ensuring the methodology delivers a rigorous, transparent analysis of techniques that are genuinely novel. Specifically, we will clearly establish how our methods are distinct from traditional methods through a comprehensive literature review and gap analysis. The methodology section will then focus on detailing the application of either genuinely new techniques or a novel combination/adaptation of existing tools that are uniquely tailored to the specific ecological and socio-economic context of Subang, thereby demonstrating the work's substantial novelty and scientific contribution.
2. The abstract describes a timely and important study that aligns with global priorities (e.g., coastal resilience and SDGs). Overall Rating: Acceptable with minor revisions. The abstract needs a brief mention of the methodology and a key finding. The full paper should be checked to ensure the promised evaluation and integration of modern technology are fully detailed and supported by data.
   Response from the authors:
   We appreciate the positive assessment of the abstract's timeliness and alignment with global priorities. We will immediately revise the abstract to incorporate a brief mention of the core methodology and at least one key finding to provide a clearer snapshot of the study's scientific contribution. Furthermore, we commit to ensuring that the full paper rigorously details and fully supports the application, evaluation, and integration of modern technology with robust data, as promised in the study's scope.
3. The introduction is strong: it effectively establishes the importance of coastal erosion, zeroes in on the problem in Subang Regency, Indonesia, and introduces the necessity of innovative, SDG-aligned mitigation

strategies. The ideas flow logically from the global issue to the local context and then to the proposed solutions.

Response from the authors:

We are pleased that the Introduction effectively establishes the study's significance, successfully moving from the global problem of coastal erosion to the local context of Subang Regency, and clearly articulating the need for innovative, SDG-aligned mitigation strategies. We will maintain this logical flow throughout the subsequent sections to ensure the rationale for our proposed solutions and their alignment with the stated research objectives remains robust and clear to the reader.

4. This text effectively combines the Study Area Description and the start of the Materials and Methods, but it needs significant restructuring and refinement to meet clear scientific publication standards.

   Response from the authors:

   We recognize the need for significant restructuring and refinement of the combined Study Area Description and the beginning of the Materials and Methods section. Our revision will clearly separate these two distinct components into their own dedicated sections: the Study Area for descriptive context and the Materials and Methods for detailed scientific procedures. We will rigorously refine the latter section to ensure it meets the highest standards of clarity, repeatability, and precision required for scientific publication.

5. The discussion is strong, offering a comprehensive and well-supported argument about the dual nature of coastal change in Subang Regency. To boost clarity and practical significance, you should: strengthen the links explaining the longshore drift direction, clarify the specific role of land use in the observed accretion, and make the interpretation of the GRDP data (Gross Regional Domestic Product) more explicit.

   Response from the authors:

   We are pleased that the Discussion is considered comprehensive and well-supported, effectively arguing for the dual nature of coastal change in Subang Regency. To enhance the clarity and practical significance as requested, we will immediately revise this section to: strengthen the explicit links between the longshore drift direction and observed coastal changes; clarify the precise role of land use in driving local accretion or erosion patterns; and make the interpretation of the GRDP data more explicit to clearly demonstrate its correlation with and impact on coastal development strategies.

6. The conclusions are excellent. They smoothly transition from presenting results to offering forward-looking recommendations based on proven strategies (hybrid systems, mangroves) and policy frameworks (ICZM - Integrated Coastal Zone Management). By repeatedly emphasizing community engagement and the Sustainable Development Goals (SDGs), the findings are effectively placed within a broader, globally relevant context.
   Response from the authors:
   We are very pleased with the assessment that the Conclusions are excellent, as they successfully transition from reporting results to offering forward-looking recommendations based on proven solutions like hybrid systems and mangroves, anchored within policy frameworks such as ICZM. We agree that the repeated and strategic emphasis on community engagement and alignment with the Sustainable Development Goals (SDGs) effectively validates the study's relevance by placing the local findings within a broader, globally significant context.

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Response to the comment from Reviewer 2

1. To maximize the title's impact and clearly define the paper's significance, I strongly recommend adding a phrase that highlights the goal or impact of the innovation. This will give the title a broader policy or sustainability angle.
   Response from the authors:
   We completely agree that maximizing the title's impact requires explicitly stating the goal or impact of our innovative approaches. We will revise the title by adding a phrase that clearly highlights the intended policy or sustainability angle, such as focusing on "coastal resilience," "sustainable development," or "integrated coastal zone management," thereby defining the paper's overarching significance and intended contribution right from the start.
2. This abstract is effective: it clearly identifies the major local problem (beach erosion in Subang Regency) and states its purpose—to explore innovative mitigation approaches that align with the Sustainable Development Goals (SDGs). It also successfully outlines the study area and mentions the key strategies being used.

Response from the authors:
We appreciate the positive feedback confirming that the abstract clearly identifies the significant local problem of beach erosion in Subang Regency and successfully articulates the purpose of exploring innovative, SDG-aligned mitigation approaches, including the necessary detail on the study area and key strategies. We will ensure the full paper delivers on the promise of innovation and alignment with the SDGs.

3. The introduction includes all the necessary elements but requires significant editing for conciseness, clarity, and flow. Most critically, the author must add a clear, explicit statement of the paper's objective and/or research question at the end. This is essential for effectively guiding the reader into the body of the paper.
   Response from the author:
   We accept the critique regarding the Introduction's need for significant editing for conciseness, clarity, and flow. Our revision will focus on streamlining the content to improve readability. Most importantly, we will add a clear and explicit statement of the paper's primary objective and/or research question at the very end of the Introduction to effectively transition the reader into the subsequent sections and guide the presentation of the study's findings.
4. The document requires reorganization. You must clearly separate the Descriptive/Contextual information (Study Area) from the Methodological/Procedural steps (Materials and Methods). Additionally, several paragraphs contain premature Results and Discussion content that should be moved.
   Response from the authors:
   We acknowledge the need for significant structural reorganization and will immediately revise the document to clearly separate the Descriptive/Contextual information (Study Area) from the Methodological/Procedural steps (Materials and Methods) into their own distinct and properly labeled sections. Furthermore, we will systematically review all sections to remove any premature Results and Discussion content, ensuring that the methodology is presented purely as procedure and that findings and their interpretation are reserved exclusively for the relevant later sections of the paper.
5. This "Results and Discussions" section is well-structured and informative. It effectively connects natural processes (accretion and erosion) with human factors (like land-use change, especially fishponds and mangrove removal). The discussion successfully identifies the main drivers: accretion: river sediment and

longshore drift and erosion: mangrove removal for fishponds. Crucially, the section successfully links these physical processes to their socio-economic impacts (threats to communities and the GRDP contribution). However, a few areas should be strengthened to improve clarity and overall impact.
Response from the authors:
We appreciate the positive feedback recognizing the "Results and Discussions" section as well-structured and effective in tying natural processes (accretion and erosion) to anthropogenic factors (land-use change) and their subsequent socio-economic impacts. We acknowledge the suggestion for strengthening certain areas and will revise the section to enhance clarity and impact by further refining the analysis of the primary drivers, ensuring a seamless and more explicit connection between the identified processes and the implications for both community resilience and the GRDP contribution.

6. The conclusions are highly effective. They successfully translated the study's data on accretion and erosion drivers into a robust policy roadmap, making them a valuable contribution to regional coastal management efforts. They only need minor editing to integrate more tightly with the specific results and strengthen the claims regarding the hybrid systems.
Response from authors:
We appreciate the strong endorsement that the Conclusions are highly effective, specifically for successfully translating the study's data on accretion and erosion drivers into a robust policy roadmap that offers valuable contributions to regional coastal management. We will execute the minor edits necessary to achieve tighter integration between the conclusions and the specific results, and we will strengthen the claims regarding the efficacy and suitability of the proposed hybrid systems based on the evidence presented in the study.

Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals

Olga Catherina Pattipawaej[1,*], Yosafat Aji Pranata[1], Robby Yussac Tallar[1], Hanny Juliani Dani[1], Gracia Artha Buating[1]

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Abstract

Beach erosion in Subang Regency poses growing environmental and socioeconomic challenges. The study area focuses on the coastal region of Subang Regency, specifically the four sub-districts: Blanakan, Sukasari, Legonkulon, and Pusakanagara. This article explores innovative mitigation approaches to address this problem, focusing on solutions aligned with the Sustainable Development Goals (SDGs). **The research utilizes geospatial technology, including high-resolution mapping and monitoring via drones,** to precisely quantify erosion rates and assess intervention areas. Strategies such as wave breaker stabilization and community-led restoration projects are then evaluated for their effectiveness in improving coastal protection, biodiversity, and the livelihoods of local communities. By integrating modern technology with ecological conservation, this innovation provides a sustainable framework for long-term coastal resilience and sustainable development in Subang Regency.

Keywords: coastal erosion, coastal protection, innovative mitigation, sustainable development goals

INTRODUCTION

Coastal erosion poses a pressing global environmental challenge, significantly threatening the sustainability and resilience of communities worldwide. Its impact extends beyond environmental damage, having significant implications for socio-economic development by undermining crucial infrastructure, disrupting essential industries, and displacing vulnerable populations (Rakhmanissazly et al., 2018). Addressing this issue with innovative and effective mitigation approaches is urgently

needed to meet the Sustainable Development Goals (SDGs) (Drestalita et al., 2021; Salim et al., 2024).

The north coast of Java, Indonesia, particularly Subang Regency, has experienced profound shoreline degradation in recent decades. This erosion results from a complex interplay of natural and human factors. Natural forces, including monsoon-induced oceanographic processes, wave action, and sea-level rise, are accelerated by anthropogenic activities. These include river development, infrastructure projects that disrupt natural sediment transport, and the conversion of protective mangrove forests for cultivation, which removes vital natural defenses (Ariffin et al., 2019). The Subang coastline, which receives outflow from major river basins like the Cilamaya and Cipunagara, is a critical area facing continuous change due to combined sedimentation and abrasion.

The consequences of this erosion are severe, affecting both environmental and economic stability in Subang Regency. As shorelines retreat, vital habitats like mangroves disappear, reducing biodiversity and natural storm protection. This, in turn, disrupts local livelihoods dependent on fisheries, tourism, and agriculture, increasing the vulnerability of local communities and damaging critical infrastructure. Therefore, effective coastal management is essential to support the region's long-term sustainable development efforts. Innovative solutions must integrate both ecological conservation and technological advancements, such as eco-engineered structures and ecosystem restoration, to build resilience against climate impacts and ensure long-term community well-being (Anu et al., 2024; Barbier, 2016).

Current literature often advocates for integrated, SDG-aligned coastal management (UNESCO, 2018; UNFCCC and IUCN, 2022). However, a significant gap remains in providing locally-specific, empirical assessments of hybrid eco-engineering strategies in the context of Subang Regency's highly dynamic environment and specific socio-economic drivers. While the potential of mangrove restoration (SDG 14) combined with physical stabilization (SDG 13) is recognized, the actual effectiveness, cost-efficiency, and community feasibility of these integrated approaches in this high-erosion area have not been adequately studied.

The primary objective of this paper is to examine and evaluate the long-term effectiveness of integrated coastal erosion mitigation strategies—specifically, the combination of mangrove restoration with eco-engineered barriers—in the most vulnerable sub-districts of Subang Regency. This study aims to provide evidence-based recommendations for sustainable coastal management that align with the regional climate resilience goals and the broader Sustainable Development Goals.

MATERIALS AND METHODS

Subang Regency (Indonesian: Kabupaten Subang), located in West Java, Indonesia, is bordered by the Java Sea to the north, Indramayu Regency to the east, Sumedang Regency to the southeast, West Bandung Regency to the south, and Purwakarta and Karawang Regencies to the west. The regency covers a total area of 2,165.55 km2, situated astronomically between 107∘30′49″–107∘54′0″ east longitude and 6∘10′59″–6∘48′59″ south latitude (BPS-Statistics Subang Regency, 2024).

The study focuses on the four coastal sub-districts: Blanakan, Sukasari, Legonkulon, and Pusakanagara, which represent the primary coastal administrative units experiencing significant shoreline changes. The areas and elevations of these sub-districts are detailed below (BPS-Statistics Subang Regency, 2024):

a. Blanakan: 103.13 km2, 5 masl
b. Sukasari: 59.65 km2, 2 masl
c. Legonkulon: 64.02 km2, 3 masl
d. Pusakanagara: 59.52 km2, 9 masl

The low elevation of Sukasari and Legonkulon (2–3 masl) highlights their inherent vulnerability to coastal processes. The region is characterized as a micro-tidal area (≤2m), with a mean tidal range of 1.0 to 1.2m, derived from tidal predictions obtained from the Geospatial Information Agency, Indonesia (BIG). Mean wave heights along the coast are recorded between 0.43–0.57m.

Historical disaster data indicates high coastal vulnerability, particularly in Legonkulon, which experienced multiple flooding events in 2021 and 2022, and a landslide in 2022. Land subsidence along the Subang Coast ranges from 0 to 5 cm/year (Handiani et al., 2022), with the villages of Pangarengan and Patimban (Pusakanagara Sub-district) recording rates over 4 mm/year.

1. Data Acquisition and Processing

a. Satellite Imagery and Geospatial Data

High-resolution Google Earth Pro (GEP) satellite imagery was the primary data source for coastline change analysis. Imagery from three distinct time points, 2003, 2013, and 2023, was acquired. The specific images used were selected based on high clarity, minimal cloud cover, and similar tidal conditions.

Topographic and geospatial base maps, including digital elevation models (DEM) and land-use data, were sourced from the Geospatial Information Agency, Indonesia (BIG). These data were integrated with the satellite imagery within a Geographic Information System (GIS) environment.

b. Drone-Based Field Survey

A drone survey was conducted in September 2024 to capture high-resolution aerial imagery and obtain accurate on-ground measurements of the current coastline and land use. The drone specifications (e.g., model, sensor) and the flight parameters (e.g., altitude, resolution) must be specified for repeatability. This imagery was processed using photogrammetry software (e.g., Pix4D, Agisoft Metashape) to generate a geo-referenced orthomosaic and a highly accurate point cloud, which served as ground truth data.

c. Land Use Classification

Land use classification for the four sub-districts in 2023 was performed by combining the BIG base map data with the high-resolution GEP and drone imagery. The land use categories identified include intensive fishponds (Tegalurung, Anggasari), urban and industrial zones (Patimban, Legonkulon, Mayangan), and coastal sandy areas (Blanakan, Tanjungtiga). This classification provided context for the human factors driving coastal change.

2. Shoreline Change Analysis

The analysis of coastline change utilized ArcGIS software, specifically the Digital Shoreline Analysis System (DSAS) add-on, to perform quantitative calculations.

a. Shoreline Digitization: Coastlines for 2003, 2013, and 2023 were manually digitized from the geo-referenced Google Earth Pro images and verified against the 2024 drone data.

b. Transect Generation: A baseline was established parallel to the general trend of the coastline, and perpendicular transects were cast across the shorelines at regular intervals (e.g., 50m or 100m).

c. Rate Calculation: The End Point Rate (EPR) method was applied to calculate the annual rate of shoreline change. The EPR is calculated by dividing the distance of movement between the two end-date shorelines (2003 and 2023) by the time elapsed between the measurements (20 years).

d. Spatial Visualization: The results were mapped (Figures 8-11) to visualize the spatial patterns of change, using a red line for 2003, a green line for 2013, and a blue line for the 2023 coastline. Positive EPR values indicate accretion, and negative values indicate erosion.

RESULTS AND DISCUSSIONS

This study analyzed coastal change processes in Subang Regency from 2003 to 2023, identifying distinct patterns of accretion and erosion driven by a combination of natural hydrodynamics and land-use shifts (Figures 2–5).

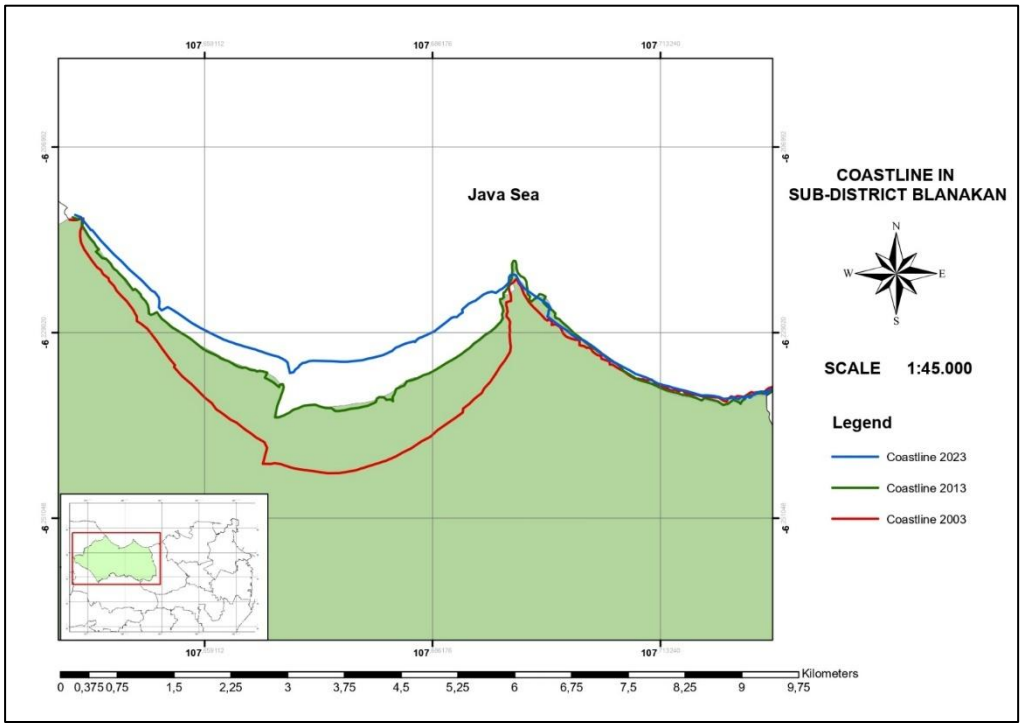

Figure 2 Coastline change at Sub-district Blanakan in 2003, 2013 and 2023

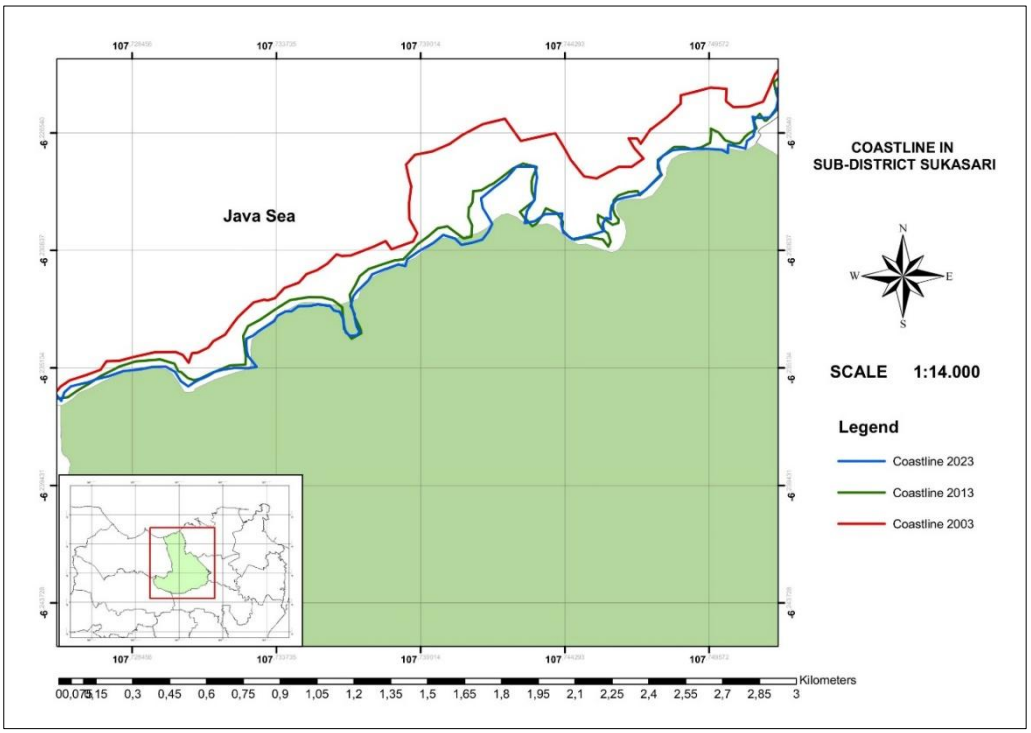

Figure 3 Coastline change at Sub-district Sukasari in 2003, 2013 and 2023

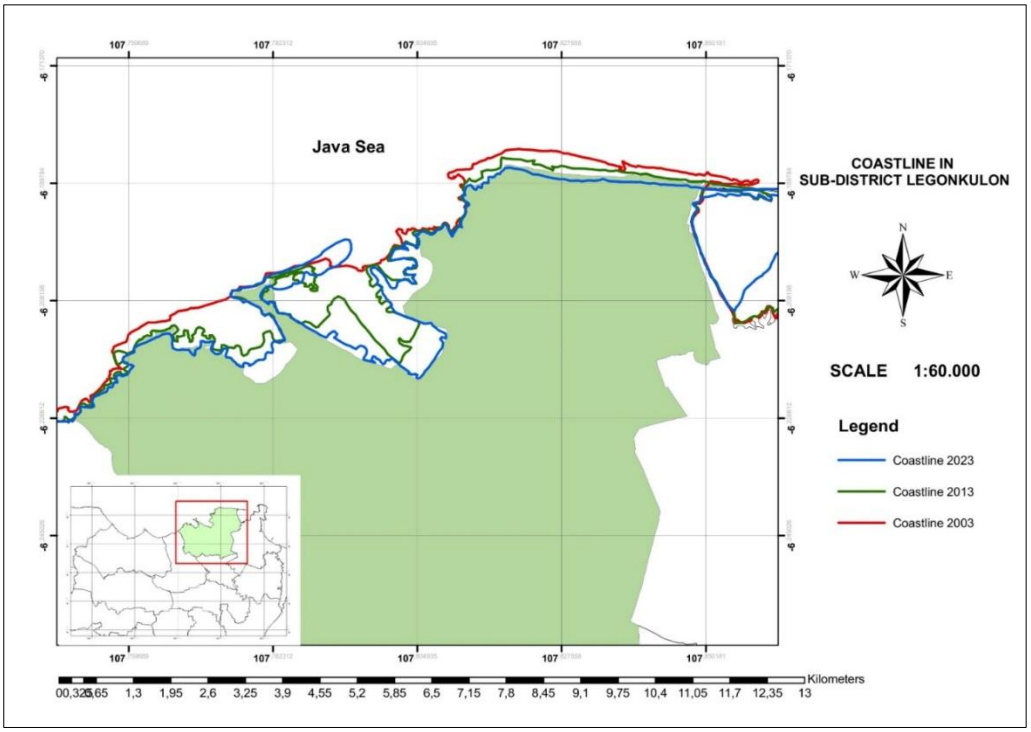

Figure 4 Coastline change at Sub-district Legonkulon in 2003, 2013 and 2023

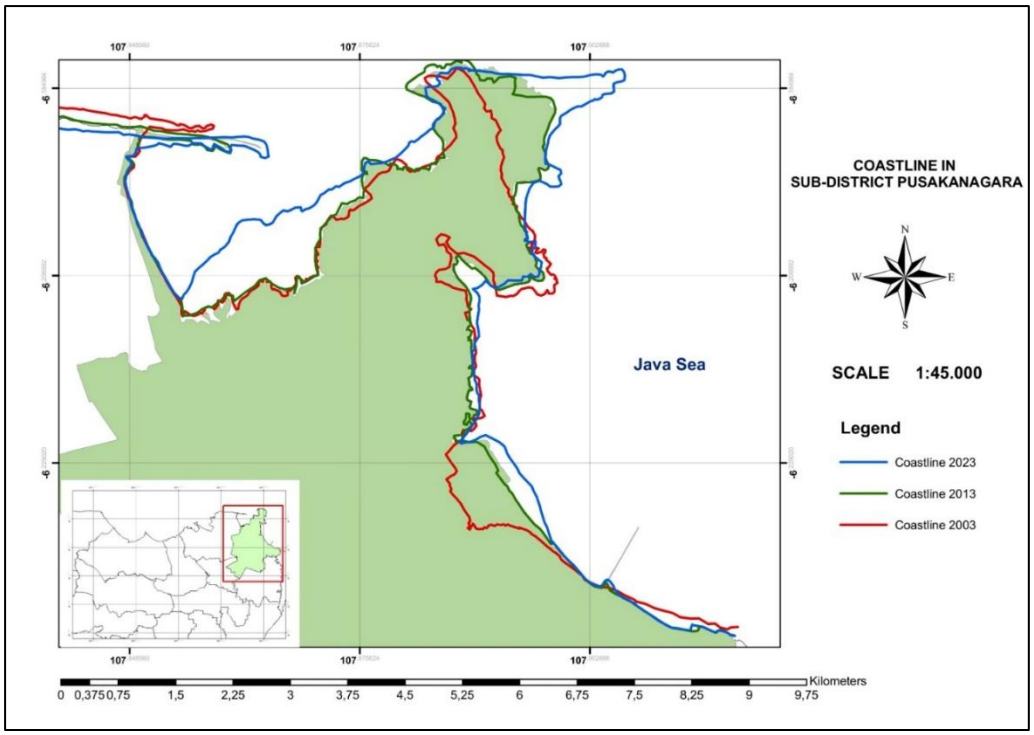

Figure 5 Coastline change at Sub-district Pusakanagara in 2003, 2013, and 2023

Accretion is concentrated in the eastern and western coastal areas, with the primary mechanism being sediment deposition from the Ciasem River and the Cipunagara River. The dominant east-to-west longshore current plays a crucial role, transporting sediment primarily from the Ciasem River westward where it settles in Blanakan Bay, a process facilitated by the area's gentler coastal slope.

Changes in land use, specifically the establishment of silvofishery practices and the successful maintenance of mangrove vegetation in these zones, have supported and stabilized this natural accretion. Despite these successes, local mangrove planting initiatives elsewhere have faced challenges due to limited monitoring of survival and growth rates, highlighting a critical need for structured management and follow-up to ensure long-term stability.

In contrast to the accreting zones, the central coastal parts—most notably the Legonkulon Sub-district—have experienced significant erosion (Figure 10). Satellite imagery confirms the recession of the shoreline since 2003. This intense erosion is primarily caused by the removal of natural protective barriers, namely mangrove forests, which historically buffered wave action and storm surges. The degradation began in the 1970s and accelerated through the 1990s (Kalther & Itaya, 2020) due to the intensive conversion of mangrove areas for the creation of fish and shrimp ponds (Figure 1). This unsustainable land-conversion practice has left the coastline highly vulnerable. Field inspections confirm this impact, showing areas of significant inland-reaching erosion and the submergence of former pond areas (Figure 1).

(a) Legonkulon subs-district in 2003

(b) Legonkulon subs-district in 2013

(c) Sub-district Legonkulon in 2023

Figure 1 Aerial Mapping of Legonkulon Sub-district in (a) 2003, (b) 2013, and (c) 2023 (Source: Google Earth Pro)

The erosion poses a direct and significant threat to coastal communities, ecosystems, and infrastructure in Legonkulon, an area characterized by high population density and a concentration of economic activities, including crop production and fisheries. This vulnerability is reflected in the regional economy. Although the Agricultural, Forestry, and Fisheries sectors contributed a substantial 30.03% of Subang's Gross Regional Domestic Product (GRDP) in 2023 (a slight decline from 30.15% in 2022), this continued erosion directly threatens the productivity of these key sectors. The observed minor decline in economic contribution may indicate the early effects of land loss and reduced yields from marine and pond areas. Addressing this ongoing coastal disaster requires targeted rehabilitation. Restoring coastal areas, particularly through mangrove revegetation, is essential for stabilizing the coastline, mitigating the impact of marine disasters, and enhancing community resilience (Indarsih & Masruri, 2019; Menéndez et al., 2020).

Effective coastal management requires a dual approach:

1. Mangrove Restoration: Prioritizing mangroves as a sustainable, nature-based solution to erosion, aligning with Sustainable Development Goals (SDGs) for climate resilience and ecosystem protection.
2. Zoning and Pond Reduction: Implementing spatial planning and reducing the extent of fishponds in designated rehabilitation zones to allow for the recovery of natural protective ecosystems. This long-term strategy is crucial for safeguarding the ecological and economic resilience of Subang's coast.

CONCLUSIONS

The findings demonstrate that coastal change in Subang Regency is characterized by rapid, human-accelerated erosion in central areas (e.g., Legonkulon Sub-district) and accretion in the east and west, driven by the removal of natural mangrove barriers for fishpond development. Mitigating this escalating threat requires a paradigm shift from unsustainable land use to a comprehensive, integrated management framework.

Addressing the severe erosion necessitates the adoption of innovative, nature-based solutions (NbS), as they offer the most sustainable path to resilience. Specifically, mangrove ecosystems are proven effective for stabilizing shorelines, reducing wave energy, and enhancing biodiversity. The most effective approach involves integrating ecological restoration with structural support through hybrid mangrove-wave breaker systems. These engineered-eco structures have shown significant potential in reducing erosion rates and creating the tranquil conditions necessary for successful mangrove establishment and long-term ecosystem recovery. Continued research and investment in these resilient systems are essential.

To secure long-term environmental and socio-economic resilience, Subang Regency must adopt an Integrated Coastal Zone Management (ICZM) framework. This framework provides the necessary structure to harmonize competing interests and coordinate efforts across governmental agencies, local communities, and industries. A successful ICZM strategy must includes Spatial Zoning (Designating clear rehabilitation zones where further fishpond development is restricted to prioritize mangrove restoration) and Sustainable Livelihoods (Integrating nature-based solutions with sustainable development strategies, such as eco-tourism and controlled, environmentally friendly silvofishery, to offer alternative economic opportunities).

The long-term success of any coastal management effort hinges on community engagement and ownership. Local communities must be actively involved in the planning, monitoring, and maintenance of restoration projects. This fosters a sense of stewardship, which is vital for the sustainability of efforts. By blending ecological restoration with socio-economic development under the ICZM framework, Subang Regency can directly contribute to the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) by building resilience to marine disasters and SDG 14 (Life Below Water) by conserving marine and coastal ecosystems for future generations.

ACKNOWLEDGEMENTS

We would like to express our sincere appreciation to the Institute for Research and Community Service, Universitas Kristen Maranatha for their generous financial support of this research project. Their funding played a crucial role in the successful execution of this study and the attainment of our research goals. The support provided by Institute for Research and Community Service, Universitas Kristen Maranatha enabled us to conduct data collection, analysis, and interpretation, as well as cover expenses related to research materials, participant recruitment, and travel, where applicable. Their investment in our work has significantly contributed to the quality and impact of our research findings.

References

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9. Artikel siap diterbitkan (25 Februari 2025)

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Thu 2/20/2025 7:40 AM

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We are happy to inform you that your research paper is accepted to be published in “Journal of Information Systems Engineering and Management".

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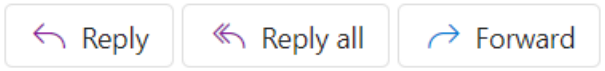

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Civil Engineering Department, Universitas Kristen Maranatha, Indonesia

**Corresponding author's e-mail address: olga.pattipawaej@eng.maranatha.edu*

We are delighted to inform you that your manuscript titled **" Innovative Approaches to Coastal Erosion Mitigation in Subang Regency: Strategies for Achieving Sustainable Development Goals"** has been accepted for publication in the upcoming issue of the Journal of Information Systems Engineering and Management.

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