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Research Article

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

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.

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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, which involve 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.

MATERIALS AND METHODS

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

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environmental challenges, needing effective coastal zone management and erosion mitigation strategies to ensure the sustainability of the coastal communities.

RESULTS AND DISCUSSION

(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)

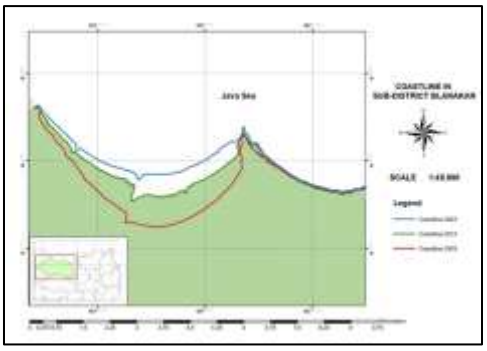

Figure 2 Coastline change at Sub-district Blanakan in 2003, 2013 and 2023

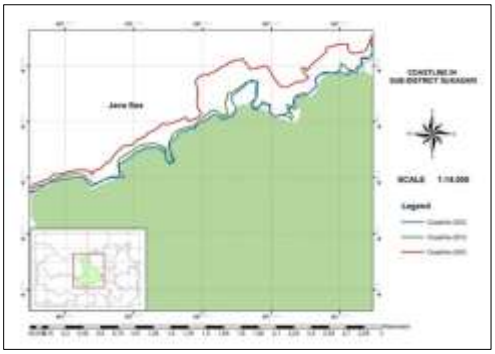

Figure 3 Coastline change at Sub-district Sukasari in 2003, 2013 and 2023

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

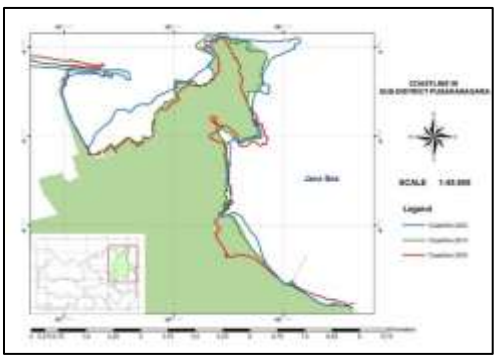

Figure 5 Coastline change at Sub-district Pusakanagara in 2003, 2013, and 2023

This study highlights the natural processes of accretion and erosion along Subang Regency's coast from 2003 to 2023 (Figures 2-5), 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

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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 4). 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 1). 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 1). 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.

CONCLUSION

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 ecotourism 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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