Journal of Smart Agriculture and Environmental Technology
e-ISSN:3021-8802
Vol. 4, No. 2, August 2026
https://josaet.com | https://doi.org/10.60105/josaet.2026.4.2.97-104

Research Paper

Mangroves as Coastal Buffer Systems: Analysis of Ecological Functions and Degradation Dynamics

Supriyanto[1]*, Dodit Ardiatma[2]

[1] *Dosen Program Studi Teknologi Hasil Pertanian dan Teknik Lingkungan, Universitas Pelita Bangsa, Bekasi*
[2] *Dosen Program Studi Teknik Lingkungan, Universitas Pelita Bangsa, Bekasi*
*__Corresponding author__: supriyanto@pelitabangsa.ac.id

Article History: Received: July 31, 2026, Accepted: August 4, 2026

Abstract

Mangrove ecosystems function as critical coastal buffer systems that provide ecological, physical, and socio-economic benefits. However, increasing anthropogenic pressures have accelerated mangrove degradation, particularly in vulnerable coastal regions such as Muara Gembong, Bekasi. This study aims to analyze the ecological functions of mangroves, identify the drivers and dynamics of degradation, and assess their implications for coastal vulnerability using a qualitative Systematic Literature Review (SLR) based on the PRISMA framework. A total of 1,860 records were initially identified, with 160 studies selected for final synthesis after a rigorous screening process. The results indicate that mangroves play a crucial role in supporting biodiversity, regulating nutrient cycles, storing blue carbon, and attenuating wave energy while stabilizing shorelines. However, these functions have significantly declined due to land-use conversion, particularly for aquaculture, along with socio-economic pressures and environmental dynamics. This degradation has increased coastal vulnerability, manifested in erosion, tidal flooding, and reduced community resilience. This study demonstrates that mangrove degradation is a multidimensional socio-ecological process and proposes an integrated analytical framework linking ecological functions, degradation dynamics, and coastal vulnerability. This framework provides a conceptual foundation for strengthening sustainable coastal management strategies in tropical regions.

Keywords

coastal buffer system; coastal vulnerability; mangrove degradation; mangrove ecosystem; Muara Gembong

1. INTRODUCTION

Mangrove ecosystems are among the most productive and ecologically significant coastal systems. Alongi (2008) emphasized that mangroves exhibit high primary productivity and resilience, enabling them to support environmental stability and human livelihoods. These ecosystems function as natural coastal buffers by reducing wave energy, preventing shoreline erosion, and protecting inland areas from extreme coastal hazards. In addition, mangroves play a crucial role in supporting biodiversity as nursery and feeding grounds for various marine organisms, while also contributing significantly to global carbon sequestration through blue carbon storage (Barbier et al., 2011; Donato et al., 2011).

Globally, mangroves have been recognized as essential nature-based solutions for climate change mitigation and coastal resilience. According to Friess et al. (2019), despite their ecological importance, mangrove ecosystems continue to experience significant degradation due to anthropogenic pressures, particularly land-use change and coastal development. In Southeast Asia, including Indonesia, mangrove deforestation rates remain among the highest in the world, largely driven by aquaculture expansion, urbanization, and resource exploitation, as reported by Giri et al. (2011).

In Indonesia, mangrove degradation has become a critical environmental issue, especially in densely populated coastal regions such as Java. One of the most affected areas is Muara Gembong, located in Bekasi Regency, West Java. This region is characterized by extensive mangrove ecosystems along the northern coast, which historically played a vital role in maintaining coastal stability. However, over the past decades, the area has experienced substantial land-use changes, particularly the conversion of mangrove forests into aquaculture ponds. Rahmawati et al. (2018) reported that such land conversion has significantly reduced mangrove coverage, while spatial analysis using remote sensing also indicates a continuous decline in mangrove extent in Muara Gembong (Pratama et al., 2022).

The consequences of these changes are reflected in the increasing intensity of shoreline dynamics and environmental degradation. Coastal erosion, seawater intrusion, and land loss have been widely documented in Muara Gembong, causing both ecological damage and economic losses for local communities. Alimuddin and Aryanti (2020) highlighted significant shoreline changes in this region, while Nugraha et al. (2019) demonstrated that land-use changes have directly influenced shoreline shifts and coastal instability. Furthermore, mangrove ecosystems in this region have undergone dynamic spatial transformations influenced by both natural processes and human activities, reflecting complex interactions between environmental and socio-economic drivers (Meizwar and Tarya, 2024).

In addition to their ecological importance, mangrove ecosystems provide substantial socio-economic benefits through ecosystem services that directly support coastal communities. These include provisioning services such as fisheries resources, regulating services such as coastal protection and climate regulation, as well as supporting ecological processes that sustain productivity. Barbier et al. (2011) emphasized the high economic value of coastal ecosystem services, indicating that mangroves contribute significantly to both environmental sustainability and local livelihoods.

In the context of Muara Gembong, the degradation of mangrove ecosystems has been closely associated with declining environmental quality and reduced economic productivity. The loss of mangrove cover has contributed to increased coastal abrasion and environmental vulnerability, which in turn affect aquaculture systems and settlement stability (Suryadi et al., 2021). In many cases, these environmental changes are directly linked to the decline of ecosystem services that previously supported coastal communities.

Moreover, mangrove degradation in Muara Gembong cannot be separated from broader socio-ecological dynamics. Coastal communities that depend heavily on aquaculture and natural resources are increasingly vulnerable to environmental changes and declining ecosystem services. Rahman and Samadi (2024) noted that this condition has led to reduced productivity of aquaculture systems and increased vulnerability of coastal settlements, thereby highlighting the urgency of understanding mangrove systems through an integrated perspective.

However, existing studies remain fragmented, often isolating ecological, physical, and socio-economic dimensions, resulting in a limited understanding of mangrove systems as integrated coastal resilience frameworks. Despite the growing body of research, most studies still focus on specific aspects such as spatial change, biodiversity, or socio-economic impacts, without adequately linking these dimensions into a unified analytical perspective. This fragmentation limits the ability to fully capture the complexity of mangrove systems, particularly in highly dynamic coastal regions such as Muara Gembong.

Therefore, this study aims to analyze the ecological functions of mangroves as coastal buffer systems and to identify the dynamics and drivers of degradation in Muara Gembong, Bekasi. The novelty of this study lies in its integrative system-based approach, which links ecological functions, degradation dynamics, and coastal vulnerability within a unified analytical framework. This approach provides a more comprehensive understanding of mangrove systems and offers a conceptual foundation for strengthening sustainable coastal management strategies.

2. EXPERIMENTAL SECTION

2.1 Study Design

This study employed a qualitative approach using a Systematic Literature Review (SLR) to synthesize and critically analyze existing knowledge on the ecological functions of mangroves and the dynamics of their degradation, particularly in Muara Gembong, Bekasi. The SLR method was selected because it enables a systematic, transparent, and reproducible evaluation of scientific literature across multiple sources. To enhance methodological rigor, the review process followed a structured protocol to ensure transparency and reproducibility. As emphasized by Snyder (2019), literature review methodologies play a crucial role in structuring and advancing knowledge within a research field. In addition, systematic reviews are widely recognized as an effective approach for integrating findings from diverse studies (Xiao and Watson, 2019).

Muara Gembong is located in the northern coastal region of Bekasi Regency, West Java, and is characterized by lowland coastal morphology, estuarine systems, and extensive mangrove ecosystems. The area is part of the Citarum River delta and directly borders the Java Sea, making it highly dynamic and vulnerable to coastal processes such as abrasion, sedimentation, and tidal flooding. These characteristics make Muara Gembong a representative study area for analyzing the ecological functions of mangroves and their role as coastal buffer systems under environmental pressure.

The geographical location of the study area is presented in Figure 1, which illustrates the administrative boundaries and coastal characteristics of Muara Gembong. The map was developed by the authors to provide a clear visualization of the study area, based on general geographic references and supported by previous spatial analyses of mangrove ecosystems in the region, such as Suryadi et al. (2021), which offer detailed information on land use and coastal conditions.

Through this approach, the study aims to provide a comprehensive understanding of the relationships between mangrove ecological functions, degradation processes, and coastal vulnerability within a specific local context.

2.2 Literature Search Strategy

The literature search was conducted systematically using several scientific databases, including Google Scholar, Scopus-indexed journals, and national journals indexed

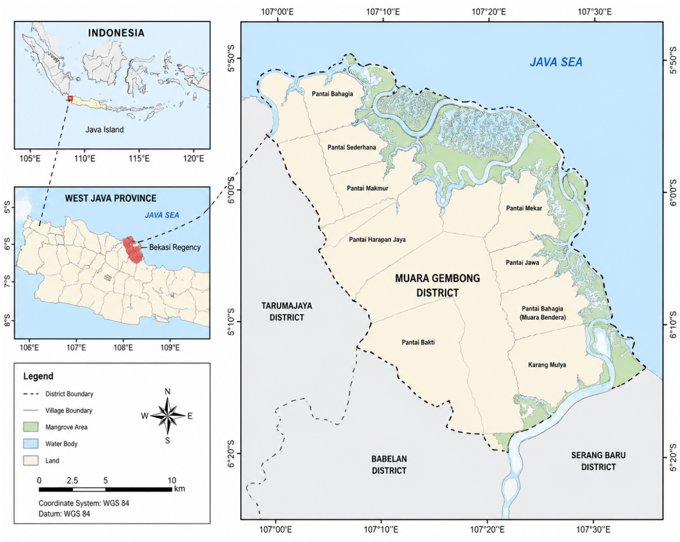

Figure 1. Study area map of Muara Gembong, Bekasi Regency (developed by the authors based on general geographic references and previous studies such as Suryadi et al. (2021)).

in SINTA. The search strategy involved combinations of keywords such as "*mangrove ecosystem*", "*coastal buffer system*", "*mangrove degradation*", "*Muara Gembong*", "*Bekasi coastal*", and "*land-use change mangrove*".

Boolean operators (AND, OR) were applied to refine the search results and improve the relevance of retrieved publications. To ensure the currency of the data, the search was limited to studies published within the last 10-15 years (2010-2025). According to Xiao and Watson (2019), a well-defined search strategy is essential to minimize bias and ensure comprehensive coverage of relevant literature.

2.3 Inclusion and Exclusion Criteria

To ensure the quality and relevance of the selected literature, predefined inclusion and exclusion criteria were applied throughout the selection process. The inclusion criteria consisted of peer-reviewed journal articles, conference proceedings, and official reports that are directly related to mangrove ecosystems, coastal protection, and environmental degradation, particularly within Indonesia or comparable tropical coastal regions.

On the other hand, non-scientific publications such as opinion articles, blogs, and non-peer-reviewed sources were excluded. Studies lacking methodological clarity, irrelevant topics, and duplicate records were also removed from the dataset. This filtering process is essential to ensure that only reliable and scientifically valid sources are included in the review (Snyder, 2019).

2.4 Literature Selection Process

The selection of literature followed a structured procedure adapted from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. Moher et al. (2009) stated that PRISMA enhances transparency and reproducibility in systematic reviews by providing a standardized process for study selection.

The process began with the identification stage, where a broad set of publications was collected from the selected databases. This was followed by the screening stage, in which titles and abstracts were reviewed to eliminate irrelevant studies. Subsequently, during the eligibility stage, full-text articles were assessed based on the predefined inclusion criteria. Finally, the inclusion stage resulted in the selection of studies that met all criteria for further analysis.

The overall selection process is illustrated using a PRISMA flow diagram (Figure 2), which presents the number of records at each stage, including identified, screened, excluded, and included studies.

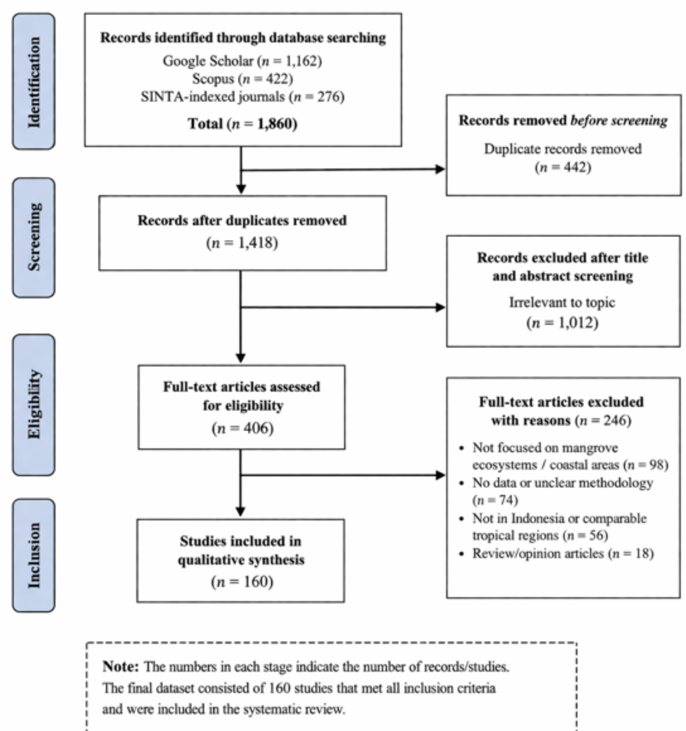

Figure 2. PRISMA Flow Diagram of the Literature Selection Process

2.5 Data Extraction

Following the selection process, relevant data from the included studies were systematically extracted and organized into several key categories. These categories included study location, ecological functions of mangroves, drivers of degradation, environmental and socio-economic impacts, and management strategies.

This structured extraction process ensures consistency in comparing findings across different studies and enhances the reliability of the synthesis. As noted by Snyder (2019), systematic data extraction is a critical step in ensuring the validity of literature review results.

2.6 Data Analysis

The extracted data were analyzed using a thematic analysis approach, which involves identifying, classifying, and interpreting recurring themes across the literature. Braun and Clarke (2006) highlighted that thematic analysis is a flexible yet rigorous method for analyzing qualitative data and identifying meaningful patterns. In this study, the literature was categorized into several major themes, including:

(1) ecological functions of mangroves,
(2) their role as coastal buffer systems,
(3) drivers and patterns of degradation,
(4) impacts on coastal vulnerability, and
(5) management and sustainability strategies.

Through this approach, the study provides an integrative understanding of the interconnections between mangrove ecological functions, degradation processes, and coastal vulnerability, thereby supporting the development of sustainable coastal management strategies.

3. RESULTS AND DISCUSSION

3.1 Ecological Functions of Mangroves

Mangrove ecosystems perform complex and multidimensional ecological functions that are essential for maintaining coastal environmental stability. Alongi (2008) emphasized that mangroves are among the most productive ecosystems in tropical coastal regions, characterized by high primary productivity and efficient nutrient cycling. These characteristics enable mangroves to support a wide range of ecological processes that sustain both marine and terrestrial life, as also highlighted in recent global assessments of mangrove ecosystems (Friess et al., 2019).

One of the most important ecological roles of mangroves is their function as critical habitats for various coastal and marine organisms. Mangrove forests provide spawning, nursery, and feeding grounds for fish, crustaceans, and mollusks, thereby contributing significantly to coastal biodiversity and fisheries productivity. Barbier et al. (2011) highlighted that the structural complexity of mangrove root systems enhances habitat heterogeneity, which supports diverse biological communities. In this context, mangroves serve as ecological connectors between terrestrial and marine ecosystems, facilitating energy flow and species interactions.

In addition to their role as habitats, mangroves are fundamental in regulating biogeochemical cycles, particularly carbon and nutrient cycles. Organic matter derived from mangrove litter undergoes decomposition processes, producing detritus that becomes a primary food source for aquatic organisms. This process strengthens trophic linkages within coastal ecosystems and enhances overall ecosystem productivity. As noted by Alongi (2008), the efficiency of nutrient recycling in mangrove systems is a key factor contributing to their ecological resilience.

Mangroves also play a strategic role in climate change mitigation through their capacity to store large amounts of carbon, commonly referred to as blue carbon. Donato et al. (2011) demonstrated that mangrove ecosystems store carbon not only in above-ground biomass but also in below-ground sediments, making them one of the most carbon-rich ecosystems globally. This carbon storage function contributes significantly to reducing atmospheric greenhouse gas concentrations and highlights the importance of mangroves in global climate regulation.

From a physical ecological perspective, mangroves contribute to sediment trapping and shoreline stabilization. Their dense root structures reduce water velocity, allowing suspended particles to settle and accumulate. This process supports land formation and helps maintain coastal geomorphology. In many coastal regions, including Muara Gembong, these functions are crucial in counteracting erosion and maintaining ecological balance, as also reflected in studies of coastal ecosystem services (Barbier et al., 2011).

In the local context of Muara Gembong, the ecological functions of mangroves are particularly significant due to the region's high environmental pressure. The presence of mangroves supports fisheries productivity and protects coastal ecosystems from degradation. However, spatial analysis indicates that changes in mangrove coverage directly influence ecosystem stability in the region. Suryadi et al. (2021) reported that the reduction of mangrove areas has weakened ecological functions and increased environmental vulnerability, particularly in coastal zones experiencing intense land-use pressure.

Overall, the findings of this study indicate that mangroves are not merely ecological components but represent integrated functional systems that regulate coastal dynamics. Their ecological roles are interconnected within a broader socio-ecological framework, thereby emphasizing the importance of mangrove conservation and sustainable management in maintaining long-term coastal resilience.

3.2 Mangroves as Coastal Buffer Systems

Mangroves play a crucial role as natural coastal buffer systems by attenuating wave energy and protecting shorelines from erosion. Alongi (2008) noted that the structural complexity of mangrove vegetation, particularly their dense root systems, enables them to act as physical barriers that reduce hydrodynamic forces before they reach inland areas. This buffering capacity is essential in minimizing the impacts of coastal hazards such as storm surges and tidal waves.

The effectiveness of mangroves in reducing wave energy has been widely documented in coastal engineering studies. Mazda et al. (2006) demonstrated that mangrove forests can significantly decrease wave height and energy, depending on vegetation density, species composition, and forest width. In many cases, wave energy can be reduced by more than 50% as it passes through dense mangrove stands. This function highlights the importance of maintaining sufficient mangrove coverage to ensure optimal coastal protection.

In addition to wave attenuation, mangroves contribute to shoreline stabilization through sediment trapping processes. Their root systems slow down water flow, allowing suspended sediments to settle and accumulate, thereby promoting land formation and reducing coastal erosion. Barbier et al. (2011) emphasized that this sediment retention capacity is a key ecosystem service that supports coastal geomorphological stability and enhances resilience against environmental changes.

From a broader perspective, mangroves are increasingly recognized as part of nature-based solutions for coastal protection and climate adaptation. According to Friess et al. (2019), mangroves provide cost-effective and sustainable alternatives to artificial coastal defenses, such as seawalls and breakwaters. Unlike engineered structures, mangroves offer multiple co-benefits, including biodiversity conservation, carbon sequestration, and support for local livelihoods.

In the context of Muara Gembong, the role of mangroves as coastal buffer systems is particularly significant due to the region's high exposure to coastal hazards. The northern coast of Bekasi has experienced severe shoreline changes and abrasion over the past decades. Alimuddin and Aryanti (2020) reported substantial coastline retreat in several areas, indicating increased vulnerability of coastal zones. The degradation of mangrove ecosystems in this region has reduced their capacity to function as effective natural barriers.

Furthermore, the conversion of mangrove areas into aquaculture ponds has weakened the structural integrity of coastal ecosystems, thereby increasing susceptibility to erosion and tidal flooding. Nugraha et al. (2019) showed that land-use changes in Muara Gembong have directly influenced shoreline dynamics, leading to increased instability of coastal areas. In many cases, the loss of mangrove vegetation has resulted in the disappearance of natural protection systems that previously mitigated coastal risks.

Suryadi et al. (2021) also highlighted that the decline in mangrove coverage in Muara Gembong is closely associated with increased environmental vulnerability, particularly in low-lying coastal areas. Without sufficient mangrove protection, coastal communities are more exposed to the impacts of wave action, flooding, and land degradation. These findings reinforce the critical importance of mangroves as frontline defenses in coastal systems.

Overall, the findings indicate that mangroves function not only as ecological components but also as dynamic coastal protection systems that integrate physical, biological, and socio-economic processes. Their ability to reduce wave energy, stabilize shorelines, and support ecosystem resilience underscores their strategic role in sustainable coastal management, particularly in vulnerable regions such as Muara Gembong.

3.3 Drivers and Dynamics of Mangrove Degradation

Mangrove degradation is a complex and multifactorial process driven by both anthropogenic and natural factors. Friess et al. (2019) highlighted that human activities remain the dominant driver of mangrove loss globally, particularly through land-use change, aquaculture expansion, and coastal development. In many tropical regions, these pressures have led to rapid declines in mangrove coverage, altering ecosystem structure and function.

One of the primary drivers of mangrove degradation is the conversion of mangrove forests into aquaculture ponds. This practice has been widely documented as a major cause of mangrove loss in Southeast Asia, including Indonesia. Giri et al. (2011) reported that large-scale land conversion has significantly reduced global mangrove extent, particularly in coastal regions undergoing rapid economic development. In the context of Indonesia, similar patterns have been observed, where mangrove areas are often transformed into shrimp ponds and other aquaculture systems due to economic incentives.

In Muara Gembong, land-use conversion represents the most significant driver of mangrove degradation. Rahmawati et al. (2018) documented extensive changes in mangrove land use, with large portions of forested areas converted into aquaculture ponds. This transformation has been further confirmed by spatial analyses, which indicate a continuous decline in mangrove coverage over time (Pratama et al., 2022). As a result, the ecological integrity of the mangrove ecosystem has been severely compromised.

In addition to direct land conversion, socio-economic factors also play a critical role in driving mangrove degradation. Coastal communities in Muara Gembong are highly dependent on aquaculture and fisheries for their livelihoods, which often leads to unsustainable resource utilization. According to Rahman and Samadi (2024), economic pressures and limited alternative income sources encourage the expansion of aquaculture into mangrove areas, thereby accelerating degradation processes.

Natural factors also contribute to mangrove degradation, although their effects are often exacerbated by human activities. Coastal dynamics such as sea-level rise, tidal fluctuations, and sediment transport influence the stability and distribution of mangrove ecosystems. However, when combined with anthropogenic disturbances, these natural processes can lead to accelerated ecosystem decline. As noted by Alongi (2008), the resilience of mangrove systems is highly dependent on their ability to adapt to changing environmental conditions, which is often constrained under degraded conditions.

The dynamics of mangrove degradation in Muara Gembong are characterized by continuous spatial and temporal changes. Nugraha et al. (2019) demonstrated that land-use changes have significantly influenced shoreline dynamics, resulting in increased coastal instability. These changes are not static but occur over time, reflecting the interaction between environmental processes and human interventions. In many cases, areas that have experienced severe degradation show limited natural recovery due to altered environmental conditions.

Furthermore, the degradation process often creates a feedback loop that reinforces environmental vulnerability. The loss of mangrove vegetation reduces the system's capacity to protect the coastline, leading to increased erosion and land loss. This, in turn, further limits the potential for mangrove regeneration, creating a cycle of degradation that is difficult to reverse. Such feedback mechanisms highlight the interconnected nature of ecological and socio-economic systems in coastal environments.

In the case of Muara Gembong, the combination of anthropogenic pressures and environmental dynamics has resulted in a highly vulnerable coastal system. The decline in mangrove coverage has not only affected ecological functions but also increased the exposure of coastal communities to environmental risks. These findings emphasize the need for integrated management approaches that address both the drivers and consequences of mangrove degradation.

Overall, the results indicate that mangrove degradation is not a single-factor phenomenon but a dynamic process influenced by complex interactions between human activities and natural systems. Understanding these drivers and their interactions is essential for developing effective strategies to mitigate degradation and promote sustainable coastal management.

This study confirms that mangrove degradation in Muara Gembong follows a coupled socio-ecological feedback mechanism, where land-use change, environmental degradation, and socio-economic pressures interact recursively, reinforcing coastal vulnerability over time.

3.4 Impacts on Coastal Vulnerability in Muara Gembong

Mangrove degradation has direct implications for increasing coastal vulnerability, particularly in low-lying coastal areas such as Muara Gembong. Friess et al. (2019) emphasized that the loss of mangrove ecosystems reduces natural coastal resilience by weakening the capacity of coastal landscapes to buffer waves, erosion, and flooding. In this context, mangroves function not only as ecological habitats but also as natural infrastructure that protects coastal settlements and economic activities.

In Muara Gembong, the decline of mangrove coverage has been closely associated with shoreline instability and coastal abrasion. Alimuddin and Aryanti (2020) reported that shoreline changes in Muara Gembong indicate a high level of coastal dynamics and environmental vulnerability. This condition is further reinforced by Nugraha et al. (2019), who demonstrated that land-use changes, particularly mangrove conversion, have influenced shoreline dynamics and increased coastal instability in the area.

The impacts of mangrove degradation are not limited to physical coastal processes but also extend to socio-economic dimensions. The loss of mangrove protection increases the exposure of aquaculture ponds, settlements, and community infrastructure to tidal flooding, erosion, and seawater intrusion. Barbier et al. (2011) highlighted that the decline of coastal ecosystem services can reduce the capacity of coastal communities to maintain livelihood security and environmental stability.

In the local context, coastal communities in Muara Gembong are highly dependent on fisheries and aquaculture activities, making them vulnerable to environmental degradation. Rahman and Samadi (2024) noted that degradation of mangrove areas has affected the potential development of mangrove-based ecotourism and local economic resilience. Therefore, coastal vulnerability in Muara Gembong should be understood as a combined result of ecological degradation, land-use pressure, and socio-economic dependence. The field condition of Muara Gembong, as shown in Figure 3, illustrates the relationship between mangrove degradation and coastal vulnerability. The visual evidence supports the literature synthesis by showing how degraded coastal landscapes may reduce natural protection functions and increase exposure to environmental hazards.

Figure 3. Field condition of Muara Gembong coastal area showing mangrove degradation and coastal vulnerability (documented by the authors, 2026).

Overall, the findings indicate that mangrove degradation in Muara Gembong contributes to a multidimensional form of coastal vulnerability. The reduction of mangrove cover weakens ecological functions, increases physical exposure to coastal hazards, and affects the socio-economic resilience of coastal communities. These conditions highlight the need for integrated coastal management that combines mangrove rehabilitation, land-use control, and community-based adaptation strategies.

3.5 Integrated Perspective and Implications for Sustainable Coastal Management

These findings collectively highlight the importance of a systems-based perspective in understanding mangrove degradation and coastal vulnerability. The synthesis of findings from this study demonstrates that mangrove ecosystems in Muara Gembong function as interconnected socio-ecological systems, where ecological processes, physical coastal dynamics, and human activities interact in complex ways. Friess et al. (2019) emphasized that mangroves should not be viewed merely as isolated ecological components, but as integral elements of coastal resilience systems that provide multiple ecosystem services simultaneously.

From an ecological perspective, the results confirm that mangroves play a fundamental role in maintaining biodiversity, regulating nutrient cycles, and supporting coastal productivity. These ecological functions are closely linked to their physical role as coastal buffer systems, which reduce wave energy, stabilize shorelines, and mitigate environmental risks. As highlighted by Barbier et al. (2011), the value of mangroves lies in their multifunctionality, where ecological and physical processes jointly contribute to coastal protection and sustainability.

However, the findings also reveal that the degradation of mangrove ecosystems in Muara Gembong is driven by a combination of anthropogenic pressures and environmental dynamics. Land-use conversion, particularly for aquaculture, remains the dominant driver of degradation, as also observed in other tropical coastal regions (Giri et al., 2011). In the local context, studies by Rahmawati et al. (2018) and Pratama et al. (2022) indicate that continuous changes in mangrove coverage have significantly altered coastal ecosystem functions, leading to increased vulnerability.

The impacts of these changes are evident in the increasing exposure of coastal areas to environmental hazards, including erosion, tidal flooding, and land loss. In Muara Gembong, this vulnerability is further exacerbated by socio-economic dependence on coastal resources. Rahman and Samadi (2024) noted that limited livelihood alternatives and economic pressures contribute to unsustainable resource use, thereby reinforcing the cycle of degradation and vulnerability.

These findings highlight the need for an integrated coastal management approach that simultaneously addresses ecological, physical, and socio-economic dimensions. According to Alongi (2008), the resilience of mangrove ecosystems depends not only on natural processes but also on effective management strategies that incorporate human interactions with the environment. In this regard, ecosystem-based management and community-based approaches are essential for restoring and sustaining mangrove functions.

The novelty of this study lies in its integrative analytical framework, which links ecological functions, degradation dynamics, and coastal vulnerability within a unified perspective. Unlike previous studies that tend to focus on a single aspect, this study synthesizes multiple dimensions to provide a more comprehensive understanding of mangrove systems in Muara Gembong. This integrated perspective allows for a deeper interpretation of how ecological degradation translates into socio-economic vulnerability and environmental risk.

Furthermore, this study contributes to the growing body of knowledge on mangrove ecosystems by emphasizing the importance of local context in understanding global environmental issues. While global studies provide general insights into mangrove functions and degradation, the case of Muara Gembong illustrates how these processes manifest at the local scale, influenced by specific socio-economic and environmental conditions.

Overall, the results underscore that sustainable coastal management in Muara Gembong requires a holistic approach that integrates mangrove conservation, land-use regulation, and community participation. By addressing both the drivers and impacts of degradation, such an approach can enhance coastal resilience and support long-term environmental sustainability.

3.6 CONCLUSION

Mangrove ecosystems in Muara Gembong play a critical role as ecological and physical coastal buffer systems that support biodiversity, regulate environmental processes, and protect coastal areas from erosion and flooding. However, this study reveals that their functions have been significantly weakened due to continuous degradation driven primarily by land-use conversion and socio-economic pressures.

The findings demonstrate that mangrove degradation in Muara Gembong is a dynamic process shaped by the interaction between anthropogenic activities and natural coastal processes, resulting in increased coastal vulnerability. The loss of mangrove cover not only disrupts ecological functions but also reduces the capacity of coastal systems to mitigate environmental risks, thereby affecting the resilience of local communities.

This study contributes an integrated perspective by linking ecological functions, degradation dynamics, and coastal vulnerability within a unified framework. Such an approach provides a more comprehensive understanding of mangrove systems compared to conventional single-aspect analyses.

Therefore, sustainable coastal management in Muara Gembong requires an integrated strategy that combines mangrove conservation, land-use regulation, and community-based approaches. Strengthening these aspects is essential to restore ecosystem functions, reduce coastal vulnerability, and ensure long-term environmental sustainability. This study provides a conceptual foundation for transforming mangrove management from sectoral approaches toward integrated socio-ecological resilience strategies.

REFERENCES

Alimuddin, A. and D. Aryanti (2020). Kajian perubahan garis pantai di Muara Gembong, Bekasi. *Jurnal Kelautan Nasional*, **15**(2); 101–110

Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, **76**(1); 1–13. https://doi.org/10.1016/j.ecss.2007.08.024

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman (2011). The value of estuarine and coastal ecosystem services. *Ecological Economics*, **70**(2); 206–213. https://doi.org/10.1016/j.ecolecon.2010.09.010

Braun, V. and V. Clarke (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, **3**(2); 77–101. https://doi.org/10.1191/1478088706qp063oa

Donato, D. C., J. B. Kauffman, D. Murdiyarso, S. Kurnianto, M. Stidham, and M. Kanninen (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, **4**(5); 293–297. https://doi.org/10.1038/ngeo1123

Friess, D. A., K. Rogers, C. E. Lovelock, K. W. Krauss, S. E. Hamilton, S. Y. Lee, R. Lucas, J. H. Primavera, A. Rajkaran, and S. Shi (2019). The state of the world's mangrove forests: Past, present, and future. *Nature Communications*, **10**; 1–15. https://doi.org/10.1038/s41467-019-07238-1

Giri, C., E. Ochieng, L. L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, and N. C. Duke (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, **20**(1); 154–159. https://doi.org/10.1111/j.1466-8238.2010.00584.x

Mazda, Y., M. Magi, M. Kogo, and P. N. Hong (2006). Mangroves as a coastal protection from waves. *Mangroves and Salt Marshes*, **1**(2); 127–135

Meizwar, D. A. and A. Tarya (2024). Dinamika Perubahan Garis Pantai di Muara Gembong, Bekasi, Jawa Barat pada Tahun 2011–2021. *Journal of Tropical Marine Science*, **7**(2); 113–127. https://doi.org/10.33019/jour.trop.mar.sci.v7i2.5063

Moher, D., A. Liberati, J. Tetzlaff, D. G. Altman, and T. P. Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine*, **6**(7); e1000097. https://doi.org/10.1371/journal.pmed.1000097

Nugraha, R. B. A., Y. Prasetyo, and S. P. Hadi (2019). The impact of land use changes on mangrove forest and shoreline dynamics in Muara Gembong, Bekasi, West Java. In *IOP Conference Series: Earth and Environmental Science*, volume 241. page 012012. https://doi.org/10.1088/1755-1315/241/1/012012

Pratama, R., A. Wibowo, and H. Setiawan (2022). Analisis sebaran spasial mangrove menggunakan citra Sentinel-2 di Muara Gembong, Bekasi. *Journal of Marine Research*, **11**(3); 215–224

Rahman, A. and R. Samadi (2024). Identifikasi pengembangan ekowisata mangrove di Desa Pantai Sederhana, Muara Gembong, Kabupaten Bekasi. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, **14**(1); 45–56. https://doi.org/10.29244/jpsl.14.1.45-56

Rahmawati, S., R. Pribadi, and C. A. Suryono (2018). Perubahan penggunaan lahan mangrove di Muara Gembong, Bekasi. *Jurnal Ilmu Kelautan*, **23**(2); 87–96

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, **104**; 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Suryadi, T., F. Yulianda, and H. A. Susanto (2021). Analisis kesesuaian kawasan konservasi mangrove di Muara Gembong, Kabupaten Bekasi Provinsi Jawa Barat. *EnviroScienteae*, **17**(3); 11–24

Xiao, Y. and M. Watson (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research*, **39**(1); 93–112. https://doi.org/10.1177/0739456X17723971