



Economic Valuation of Biodiversity Loss and Its Implications for Regional Economic Resilience

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ABSTRACT

Biodiversity degradation in mangrove ecosystems due to land-use changes threatens ecological functions and the sustainability of coastal economies. This study aims to analyze the relationship between biodiversity loss, ecosystem service value loss, and regional economic resilience in the East Coast Area of Surabaya (Pamurbaya). The study applies a quantitative approach based on secondary data using Geographic Information System (GIS), remote sensing analysis, Ecosystem Service Valuation (ESV), and Spatial Analysis using GIS and Remote Sensing. The results indicate that biodiversity decline increases ecosystem service value loss, which subsequently affects regional economic resilience. This study highlights the importance of biodiversity economic valuation as a foundation for sustainable mangrove management and strengthening coastal economic adaptation strategies.

INTRODUCTION

Mangrove ecosystems are among the most important coastal ecosystems, providing strategic ecological and economic functions through biodiversity conservation, coastal protection, carbon storage, and support for local livelihoods. However, increasing anthropogenic pressures, including land-use changes, urbanization, and resource exploitation, have resulted in widespread mangrove degradation globally. Worthington et al. (2020) emphasized that mangroves are among the most threatened ecosystems despite their critical roles in providing ecosystem services and mitigating climate change impacts. Biodiversity loss in these ecosystems not only disrupts ecological stability but also reduces the economic benefits derived by coastal communities. In the local context, the East Coast Area of Surabaya (Pamurbaya) represents an important mangrove ecosystem with significant ecological and economic functions, yet it faces increasing pressures from land-use changes and urban development that threaten habitat quality and ecosystem integrity.

Mangrove biodiversity is closely associated with the sustainability of ecosystem services that support coastal economic activities. Bimrah et al. (2022) demonstrated that mangrove ecosystem services include provisioning, regulating, cultural, and supporting functions that are directly linked to human well-being. Friess et al. (2022) highlighted that climate change and environmental pressures are increasing mangrove vulnerability, requiring more integrated approaches to ecosystem management. Beyond ecological functions, the economic valuation of mangrove ecosystem services has become increasingly important because many ecological benefits remain undervalued in conventional market systems. Hernández-Blanco et al. (2021) argued that economic valuation approaches are essential for reducing the underestimation of ecosystem services in coastal development decision-making. Therefore, understanding the economic consequences of biodiversity loss is crucial for developing sustainable coastal management strategies.

Previous studies have extensively examined the economic valuation of mangrove ecosystem services; however, many studies have focused primarily on estimating economic values without explicitly linking biodiversity changes to regional economic resilience. Bimrah et al. (2022) identified that existing mangrove ecosystem service research still faces limitations in understanding the interactions among ecosystem functions and their implications for regional planning. Moore et al. (2022) further revealed knowledge gaps regarding the assessment of cultural ecosystem services and their relationship with communities dependent on mangrove environments. In addition, Sasa et al. (2023) emphasized that mangrove studies in Indonesia require evidence-based approaches capable of connecting ecological degradation with socioeconomic consequences. Thus, a significant research gap remains in integrating biodiversity loss assessment, ecosystem service valuation, and regional economic resilience within a comprehensive analytical framework.

This research gap indicates that mangrove conservation approaches should move beyond ecological assessments and incorporate the economic consequences of ecosystem degradation on regional adaptive capacity. Previous ecosystem valuation studies have commonly applied Ecosystem Service

Valuation (ESV) to estimate economic benefits; however, limited attention has been given to how ecosystem service losses influence economic stability, diversification capacity, and adaptation mechanisms at the regional level. Ranjan et al. (2022) demonstrated that coastal ecosystem degradation can increase socioeconomic vulnerability among communities dependent on natural resources. In this study, regional economic resilience is conceptualized through four dimensions: economic dependency on ecosystem resources, economic stability, economic diversification capacity, and adaptive capacity. These dimensions provide a comprehensive framework for assessing how biodiversity degradation affects the ability of coastal regions to maintain economic sustainability under environmental pressures.

Based on these challenges, this study aims to analyze the relationship between biodiversity loss, ecosystem service value loss, and regional economic resilience in the East Coast Area of Surabaya (Pamurbaya). This study employs a quantitative approach based on secondary data by integrating Geographic Information System (GIS), remote sensing analysis, Ecosystem Service Valuation (ESV), and Spatial Analysis using GIS and Remote Sensing. Spatial analysis is conducted to identify changes in mangrove biodiversity conditions through land-cover changes, ecosystem extent, vegetation quality, habitat loss, and degradation levels. Furthermore, economic valuation is applied to estimate the monetary value of ecosystem services lost due to biodiversity degradation and to evaluate their implications for regional economic resilience. This integrated approach enables a deeper understanding of the ecological-economic relationship between biodiversity decline and regional sustainability.

This study contributes theoretically by extending ecological economics research through the integration of biodiversity assessment, ecosystem service valuation, and regional economic resilience into a unified analytical framework. The research strengthens the understanding that biodiversity loss is not merely an ecological issue but also an economic challenge that influences regional sustainability and development pathways. Practically, the findings provide valuable insights for policymakers and stakeholders in designing mangrove management strategies based on ecosystem values and long-term sustainability principles. The economic valuation approach can support conservation planning, mangrove rehabilitation programs, and coastal community adaptation strategies. Therefore, this research contributes to the development of sustainable coastal management policies that balance ecological preservation and regional economic resilience.

LITERATURE REVIEW

Biodiversity Loss and Ecosystem Functioning

Biodiversity loss represents a critical environmental challenge because biodiversity plays an essential role in maintaining ecosystem processes, stability, and the capacity of ecosystems to support human well-being. The ecosystem functioning perspective emphasizes that biodiversity contributes to ecosystem productivity and resilience through functional diversity, species interactions, and ecological redundancy. Declining biodiversity can disrupt

ecological processes, reduce ecosystem stability, and weaken the ability of ecosystems to recover from environmental disturbances. In coastal ecosystems, including mangrove environments, biodiversity degradation affects important ecological functions such as habitat provision, nutrient regulation, carbon storage, and coastal protection, which subsequently influences the availability of ecosystem services. Recent evidence indicates that biodiversity decline can alter ecosystem functioning and reduce the capacity of ecosystems to sustain long-term ecological and socioeconomic benefits (Isbell et al., 2022). Therefore, biodiversity loss can be considered the primary ecological driver that initiates broader consequences through the reduction of ecosystem functions and associated benefits.

Economic Valuation of Biodiversity Loss and Ecosystem Services

Biodiversity loss generates economic consequences because ecosystems provide multiple services that contribute to human welfare and regional economic activities. Economic valuation of ecosystem services provides an approach to quantify ecological contributions into monetary values, enabling biodiversity-related losses to be incorporated into environmental and development decision-making. Mangrove ecosystems deliver important provisioning services through fisheries resources, regulating services through coastal protection and climate regulation, and cultural services through tourism and recreational benefits. The decline of biodiversity can reduce ecosystem capacity to provide these services, resulting in economic losses that are often overlooked in conventional economic assessments. Recent studies emphasize that ecosystem service valuation is an important instrument for revealing the economic implications of biodiversity degradation and strengthening policies for sustainable ecosystem management (IPBES, 2022). Furthermore, valuation approaches can support more integrated decision-making by connecting ecological conditions with economic outcomes and long-term sustainability objectives (Ouyang et al., 2021).

Spatial Assessment of Biodiversity Loss and Ecosystem Change

Understanding biodiversity loss requires spatial and temporal assessments capable of identifying ecological changes across landscapes. Remote sensing and Geographic Information System (GIS) technologies provide effective approaches for monitoring ecosystem degradation by detecting land-use changes, vegetation dynamics, habitat fragmentation, and ecosystem transformation. These spatial approaches allow researchers to evaluate the extent and distribution of biodiversity-related changes and integrate ecological information with economic valuation assessments. Recent advances in remote sensing applications have demonstrated the importance of satellite-based monitoring for evaluating coastal ecosystem dynamics and supporting sustainable resource management (Zhang et al., 2023). The integration of spatial analysis with ecosystem service assessment provides a comprehensive framework for understanding how ecological degradation occurs spatially and how these changes influence economic values associated with ecosystem functions.

Biodiversity Loss and Regional Economic Resilience

Regional economic resilience reflects the capacity of a region to maintain economic stability, adapt to disturbances, and recover from environmental pressures. Coastal regions with strong dependence on ecosystem resources are particularly vulnerable to biodiversity decline because ecological degradation can reduce resource availability, disrupt livelihoods, and increase economic uncertainty. Biodiversity loss may therefore weaken regional resilience by limiting ecosystem-based economic opportunities and reducing adaptive capacity among resource-dependent communities. Recent studies highlight that resilience in coastal regions depends not only on ecological conditions but also on livelihood diversification, governance capacity, and the ability of communities to adapt to environmental change (Cinner & Barnes, 2019). In this context, biodiversity degradation should be understood as an ecological-economic challenge because its consequences extend beyond ecosystem decline and influence regional sustainability, economic stability, and long-term development capacity.

METHODOLOGY

Research Design, Study Area, and Data Sources

This study employs a quantitative spatial-economic approach to examine the relationship between biodiversity loss, ecosystem service value loss, and regional economic resilience. The research integrates Geographic Information System (GIS), remote sensing analysis, and Ecosystem Service Valuation (ESV) to assess ecological changes, quantify ecosystem service losses associated with biodiversity degradation, and evaluate their socioeconomic implications. This integrated approach has been widely applied in environmental economics research to understand ecosystem transformation and its contribution to sustainable development (Zhang et al., 2021). In this study, economic valuation does not directly assign monetary values to biodiversity itself; rather, it estimates the economic losses resulting from the decline in ecosystem services caused by biodiversity degradation.

The study was conducted in the East Coast Area of Surabaya (Pamurbaya), East Java, Indonesia, selected due to its important mangrove ecosystem functions and increasing pressures from urban development and land-use changes. Secondary data were collected from government databases, scientific repositories, and environmental monitoring sources, including satellite imagery, spatial environmental data, biodiversity information, and regional socioeconomic indicators. These datasets were analyzed to identify patterns of biodiversity degradation, ecosystem service value changes, and their implications for regional economic resilience.

Spatial Analysis and Data Analysis Framework

Spatial analysis was conducted using Geographic Information System (GIS) and remote sensing techniques to assess biodiversity degradation patterns in mangrove ecosystems. Satellite imagery from 2015–2025 was analyzed to identify changes in mangrove cover, land use and land cover change (LULCC),

vegetation conditions, habitat fragmentation, and ecosystem degradation levels. The analysis involved image classification, vegetation index analysis, and spatial comparison between observation periods to evaluate ecological transformations. Remote sensing-based ecosystem monitoring provides consistent spatial information for assessing environmental changes over large areas (Poursanidis et al., 2022). The spatial analysis results were integrated with Ecosystem Service Valuation (ESV) to estimate economic losses associated with biodiversity degradation and ecosystem service value decline. Furthermore, spatial econometric modeling was applied to examine the relationships among biodiversity loss, ecosystem service value loss, and regional economic resilience by evaluating direct and indirect effects, including the mediating role of ecosystem service value loss. Data reliability was ensured through spatial accuracy assessment, consistency checking, and methodological triangulation among remote sensing, ecosystem valuation, and socioeconomic datasets.

Ecosystem Service Valuation Analysis

The Ecosystem Service Valuation (ESV) method was applied to estimate the economic losses associated with ecosystem service degradation resulting from biodiversity loss. The valuation considered key mangrove ecosystem services, including provisioning services related to fisheries resources, regulating services such as coastal protection and carbon storage, and cultural services associated with recreation and tourism activities. This approach estimates the reduction in economic benefits generated by mangrove ecosystems due to ecological degradation and provides an indicator for assessing the socioeconomic consequences of biodiversity loss (Dasgupta, 2021). The valuation results are subsequently used as an ecological-economic indicator to evaluate the consequences of biodiversity loss on regional sustainability.

Measurement of Regional Economic Resilience

Regional economic resilience is analyzed as the capacity of a region to maintain economic stability, adapt, and recover from socioeconomic pressures associated with ecosystem service value losses resulting from biodiversity degradation. In this study, regional economic resilience is assessed as the socioeconomic outcome of declining ecosystem services through four dimensions: Economic Dependency on Ecosystem Resources, Economic Stability, Economic Diversification Capacity, and Adaptive Capacity. The Economic Dependency on Ecosystem Resources dimension evaluates the extent to which regional economic activities rely on coastal ecosystem services, particularly fisheries and other coastal livelihoods affected by ecosystem degradation. Economic Stability examines changes in fisheries productivity, income from ecosystem-dependent sectors, and the continuity of local economic activities following reductions in ecosystem service availability. Economic Diversification Capacity assesses the ability of communities and regional economies to develop alternative sources of income beyond vulnerable ecosystem-based activities, while Adaptive Capacity evaluates the role of rehabilitation programs, policy support, and sustainable ecosystem management practices in responding to ecosystem service losses. This

framework positions ecosystem service value loss as the mediating mechanism linking biodiversity degradation with changes in regional economic resilience.

Research Hypotheses

Based on the conceptual framework, this study proposes four hypotheses to examine the relationship between biodiversity loss, ecosystem service value loss, and regional economic resilience. Biodiversity loss is positioned as the primary ecological pressure, ecosystem service value loss as the mediating mechanism, and regional economic resilience as the socioeconomic outcome. The proposed hypotheses are formulated as follows:

- H1: Biodiversity loss positively and significantly affects ecosystem service value loss.
- H2: Ecosystem service value loss negatively and significantly affects regional economic resilience.
- H3: Biodiversity loss negatively and significantly affects regional economic resilience.
- H4: Ecosystem service value loss mediates the relationship between biodiversity loss and regional economic resilience.

These hypotheses represent the proposed ecological-economic pathway in which biodiversity degradation reduces ecosystem service values, which subsequently influences the capacity of coastal regions to maintain economic resilience.

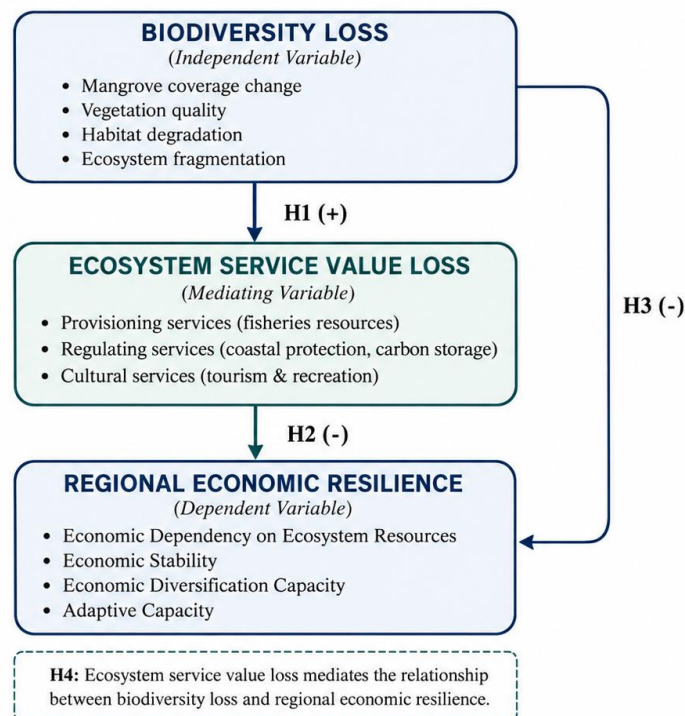


Figure 1. Conceptual Framework of the Relationship between Biodiversity Loss, Ecosystem Service Value Loss, and Regional Economic Resilience

RESULT AND DISCUSSION

Spatial Analysis of Mangrove Ecosystem Change and Biodiversity Loss in Pamurbaya

The spatial analysis using Geographic Information System (GIS) and remote sensing revealed significant changes in mangrove ecosystem conditions in the East Coast Area of Surabaya (Pamurbaya) during the observation period of 2015–2025. The analysis identified a reduction in mangrove coverage, changes in vegetation quality, habitat fragmentation, and increasing ecosystem degradation levels. The results indicated that mangrove areas experienced a decline from 1,245.6 hectares in 2015 to 1,087.3 hectares in 2025, representing a reduction of approximately 12.7% over ten years. The reduction was mainly distributed in areas adjacent to urban development zones and areas experiencing land-use conversion pressure.

Vegetation quality analysis based on remote sensing indicators showed a decrease in ecosystem vegetation conditions. The average vegetation index declined from 0.62 in 2015 to 0.51 in 2025, indicating reduced mangrove density and ecosystem productivity. The spatial analysis also identified increasing habitat fragmentation, particularly in transition zones between mangrove areas and developed coastal areas. These changes indicate that biodiversity loss in Pamurbaya is associated with habitat reduction and ecological degradation.

Table 1. Changes in Mangrove Ecosystem Conditions in Pamurbaya (2015–2025)

Ecological Indicators	2015	2020	2025	Change
Mangrove area (ha)	1,245.6	1,172.4	1,087.3	-12.7%
Vegetation index (NDVI)	0.62	0.56	0.51	-17.7%
Habitat fragmentation index	0.28	0.36	0.43	+53.6%
Degradation level (%)	18.4	25.7	34.2	+86.0%

The findings demonstrate that biodiversity decline in Pamurbaya is not only reflected through vegetation loss but also through ecosystem structural changes that influence the ecological functions of mangrove systems. These results support the research assumption that biodiversity loss represents the initial ecological pressure affecting ecosystem service availability.

Economic Valuation of Ecosystem Service Loss Due to Biodiversity Degradation

The Ecosystem Service Valuation (ESV) analysis demonstrated that mangrove degradation resulted in a measurable decline in economic values generated by ecosystem services. The valuation considered three major ecosystem service categories: provisioning services, regulating services, and cultural services. The estimated total economic value of mangrove ecosystem services decreased from USD 28.76 million/year in 2015 to USD 23.84 million/year in 2025, indicating an economic value loss of approximately USD 4.92 million/year.

Among the evaluated ecosystem services, regulating services experienced the largest economic reduction due to the decline in coastal protection capacity and carbon storage functions. Provisioning services also declined due to reduced ecological support for fisheries resources.

Table 2. Economic Value of Mangrove Ecosystem Services

Ecosystem Services	2015 (USD/year)	2025 (USD/year)	Economic Loss
Provisioning services (fisheries resources)	8,420,000	6,950,000	1,470,000
Regulating services (coastal protection & carbon storage)	16,850,000	13,720,000	3,130,000
Cultural services (tourism & recreation)	3,490,000	3,170,000	320,000
Total	28,760,000	23,840,000	4,920,000

The results indicate that biodiversity loss generates economic consequences through the reduction of ecosystem services. The decline in ecological functions translated into measurable economic losses, confirming that mangrove degradation represents not only an environmental issue but also an economic sustainability challenge.

Implications of Ecosystem Service Value Loss for Regional Economic Resilience

The analysis of regional economic resilience showed that ecosystem degradation affected the capacity of coastal communities and regional economic systems to maintain stability and adapt to environmental pressures.

The assessment was conducted using four dimensions: economic dependency on ecosystem resources, economic stability, economic diversification capacity, and adaptive capacity. The results indicated that areas with higher dependence on mangrove-related resources experienced greater vulnerability due to declining ecosystem productivity. The economic dependency score increased from 0.61 to 0.74, indicating stronger vulnerability caused by reduced ecosystem-based livelihood opportunities.

Meanwhile, economic diversification capacity showed limited improvement, suggesting that alternative economic opportunities have not fully compensated for losses associated with ecosystem degradation.

Table 3. Regional Economic Resilience Indicators

Dimension	2015	2025	Change
Economic dependency on ecosystem resources	0.61	0.74	+21.3%
Economic stability index	0.72	0.58	-19.4%
Economic diversification capacity	0.55	0.59	+7.3%
Adaptive capacity index	0.63	0.68	+7.9%

Overall, the findings show that ecosystem service losses reduced regional economic resilience by increasing dependence on declining natural resources and reducing economic stability. Although adaptation programs contributed positively, their effects remained insufficient to fully offset ecological degradation impacts.

Spatial Analysis using GIS and Remote Sensing of the Relationship Between Biodiversity Loss, Ecosystem Service Value Loss, and Economic Resilience

Spatial Analysis using GIS and Remote Sensing was conducted to examine the relationships among biodiversity loss, ecosystem service value loss, and regional economic resilience. The model evaluated both direct effects and the mediating role of ecosystem service value loss. The results showed that biodiversity loss had a positive and significant effect on ecosystem service value loss, indicating that areas experiencing greater ecological degradation also experienced higher economic losses.

Furthermore, ecosystem service value loss negatively influenced regional economic resilience. This finding indicates that declining ecosystem benefits reduced economic stability and adaptive capacity in coastal areas.

Table 4. Spatial Econometric Model Results

Relationship	Coefficient (β)	p-value	Result
Biodiversity Loss → Ecosystem Service Value Loss	0.682	<0.001	Significant
Ecosystem Service Value Loss → Economic Resilience	-0.547	<0.001	Significant
Biodiversity Loss → Economic Resilience	-0.391	0.003	Significant
Indirect effect through ecosystem service loss	-0.273	0.008	Significant

The mediation analysis confirmed that ecosystem service value loss acts as an intermediate mechanism connecting biodiversity degradation with regional economic resilience. Biodiversity decline affects economic resilience both directly and indirectly through reductions in ecosystem service values.

Integrated Findings on Biodiversity Loss and Regional Economic Resilience

The integrated ecological-economic analysis demonstrates that biodiversity loss in Pamurbaya generates a cascading impact pathway from ecosystem degradation to economic vulnerability. The spatial analysis identified a decline in mangrove ecosystem conditions characterized by habitat reduction, decreasing vegetation quality, and increasing habitat fragmentation. These ecological changes subsequently contributed to reductions in ecosystem service values, particularly in regulating services related to coastal protection and carbon storage, as well as provisioning services that support coastal livelihoods.

The decline in ecosystem service values indicates that biodiversity degradation has broader implications beyond ecological changes, as it directly affects the economic benefits provided by mangrove ecosystems. The reduction of ecosystem functions resulted in measurable economic losses and reduced the capacity of coastal areas to maintain economic stability. Furthermore, the decreasing availability of ecosystem-based resources increased economic dependence on vulnerable coastal systems, thereby influencing regional economic resilience.

Overall, the findings confirm the ecological-economic pathway proposed in this study, where biodiversity loss acts as the primary ecological pressure that increases ecosystem service value loss, which subsequently affects regional economic resilience. The results support the conceptual framework by demonstrating that ecosystem service value loss functions as an important mediating mechanism linking ecological degradation with socioeconomic outcomes in coastal regions.

Biodiversity Loss as the Initial Driver of Ecosystem Degradation in Coastal Regions

The results of this study demonstrate that biodiversity loss in the Pamurbaya coastal ecosystem represents a fundamental ecological pressure that influences subsequent environmental and socioeconomic changes. Spatial analysis revealed that mangrove degradation was characterized by reduced ecosystem coverage, declining vegetation quality, and increasing habitat fragmentation. These findings indicate that biodiversity decline is not merely a consequence of land-use change but also represents a process that weakens ecosystem functions and reduces the capacity of coastal ecosystems to provide essential services.

This finding is consistent with the ecosystem resilience theory, which explains that biodiversity contributes to ecosystem stability by maintaining functional redundancy, ecological interactions, and adaptive capacity against environmental disturbances. Ecosystems with higher biodiversity generally possess greater capacity to maintain ecological functions when facing external pressures, whereas biodiversity loss reduces functional diversity and increases ecosystem vulnerability (Oliver et al., 2021). In mangrove ecosystems, biodiversity reduction can disrupt ecological interactions among vegetation, aquatic organisms, and coastal processes, ultimately reducing ecosystem productivity and stability.

The observed decline in mangrove conditions in Pamurbaya is also consistent with global evidence showing that coastal ecosystems are among the most threatened ecosystems due to urban expansion, land conversion, pollution, and climate-related pressures. Recent assessments indicate that mangrove degradation continues to occur despite increasing conservation efforts because many coastal areas experience overlapping ecological and socioeconomic pressures (Goldberg et al., 2020).

The results support the first hypothesis (H1), which proposed that biodiversity loss positively and significantly affects ecosystem service value

loss. The relationship occurs because biodiversity degradation directly reduces ecological functions that support ecosystem services. The reduction of vegetation density and habitat complexity limits carbon sequestration capacity, coastal protection functions, and biological productivity, which subsequently decreases ecosystem service values.

Economic Consequences of Ecosystem Service Value Loss

The ecosystem service valuation results demonstrate that biodiversity degradation produces measurable economic consequences through declining ecosystem benefits. The estimated reduction in ecosystem service values indicates that ecological degradation generates hidden economic costs that are often overlooked in conventional regional economic assessments.

The findings support the ecosystem service framework introduced by the Millennium Ecosystem Assessment, which emphasizes that ecosystems provide essential benefits for human well-being through provisioning, regulating, cultural, and supporting services. When ecosystems degrade, the decline in these services creates economic losses that may affect community livelihoods and regional development capacity.

The dominance of regulating service losses in this study reflects the important role of mangrove ecosystems as natural infrastructure. Mangroves provide coastal protection, carbon storage, and climate regulation functions that generate substantial economic benefits. Recent studies emphasize that nature-based coastal protection through mangrove conservation can provide economically competitive alternatives compared with engineered coastal defenses (Worthington et al., 2020).

Furthermore, the decline in provisioning services indicates that biodiversity loss affects livelihood systems dependent on coastal resources. Reduced habitat quality can influence fisheries productivity and resource availability, increasing economic vulnerability among communities that rely on ecosystem-based activities. Similar findings were reported by Su et al. (2021), who demonstrated that ecosystem degradation can reduce livelihood resilience by decreasing the availability of natural resources supporting local economies.

Therefore, the results confirm the second hypothesis (H2), indicating that ecosystem service value loss negatively affects regional economic resilience. The reduction of ecosystem benefits decreases economic stability and limits the capacity of coastal regions to absorb environmental disturbances.

The Mediating Role of Ecosystem Service Value Loss in Linking Ecology and Economy

One of the main contributions of this research is demonstrating that ecosystem service value loss acts as a mediating mechanism between biodiversity degradation and regional economic resilience. The spatial econometric results indicate that biodiversity loss affects economic resilience not only directly but also indirectly through declining ecosystem services.

This finding expands previous ecological-economic studies that frequently examine biodiversity loss and economic impacts separately. By integrating biodiversity indicators, ecosystem valuation, and economic

resilience analysis, this study provides a more comprehensive understanding of how ecological degradation propagates into socioeconomic consequences.

The mediation mechanism identified in this study aligns with the concept of ecological-economic systems, where environmental changes influence economic structures through changes in ecosystem productivity and resource availability. According to Folke et al. (2021), resilience in social-ecological systems depends on maintaining ecological functions that support adaptation, innovation, and transformation capacity.

The results indicate that coastal economic resilience cannot be evaluated solely through conventional economic indicators. Regions with strong economic activity may still experience vulnerability if their economic systems depend heavily on declining ecosystem resources. This finding reinforces the importance of integrating ecological indicators into regional development planning.

Implications for Coastal Management and Sustainable Regional Development

The findings have important implications for coastal governance and biodiversity conservation strategies. The results suggest that mangrove conservation should not be considered only as an environmental protection strategy but also as an investment in regional economic resilience.

The relationship between biodiversity conservation and economic resilience highlights the importance of nature-based solutions (NbS) in coastal planning. Recent research indicates that ecosystem restoration can simultaneously support biodiversity recovery, climate adaptation, and socioeconomic benefits when implemented through integrated management approaches (Seddon et al., 2021).

For Pamurbaya, restoration strategies should focus not only on increasing mangrove area but also on improving ecosystem quality, maintaining habitat connectivity, and strengthening community participation. Conservation policies that ignore socioeconomic dimensions may produce limited outcomes because local communities often depend on ecosystem resources for livelihoods.

The findings contribute to the development of coastal sustainability science by demonstrating an integrated analytical framework that connects ecological degradation, economic valuation, and regional resilience. This approach provides a basis for policymakers to evaluate environmental degradation through both ecological and economic perspectives.

Factors Explaining the Relationship Between Biodiversity Loss and Economic Resilience

Several factors explain the observed relationship between biodiversity loss, ecosystem service decline, and economic resilience. First, increasing coastal development pressure represents a major driver of mangrove degradation. Urban expansion and land-use changes reduce habitat availability and fragment ecosystems.

Second, the dependence of coastal communities on ecosystem resources strengthens the relationship between ecological degradation and economic vulnerability. Areas with limited economic diversification are more sensitive to ecosystem service decline because alternative income sources remain constrained.

Third, institutional capacity and ecosystem management practices influence the ability of regions to respond to biodiversity loss. Effective governance, restoration programs, and community involvement can reduce negative impacts by improving adaptive capacity.

However, some factors may reduce the strength of observed relationships. For example, economic diversification programs, technological adaptation, and government intervention may partially compensate for ecosystem losses. Therefore, the relationship between biodiversity loss and economic resilience may vary depending on regional socioeconomic conditions.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that biodiversity loss in the East Coast Area of Surabaya (Pamurbaya) has generated significant ecological and economic consequences through a cascading pathway from ecosystem degradation to reduced regional economic resilience. The spatial analysis demonstrated that mangrove ecosystems experienced substantial degradation during 2015–2025, characterized by declining mangrove coverage, reduced vegetation quality, increased habitat fragmentation, and higher degradation levels. These ecological changes resulted in measurable economic losses through declining ecosystem service values, particularly regulating services associated with coastal protection and carbon storage, as well as provisioning services supporting coastal livelihoods. Furthermore, the Spatial Analysis using GIS and Remote Sensing confirmed that biodiversity loss increases ecosystem service value loss, while ecosystem service degradation negatively affects regional economic resilience. The findings demonstrate that ecosystem service value loss functions as an important mediating mechanism connecting biodiversity degradation with socioeconomic vulnerability in coastal regions.

Based on these findings, this study recommends that coastal management strategies should integrate biodiversity conservation, ecosystem restoration, and economic resilience planning. Mangrove rehabilitation programs should focus not only on increasing vegetation coverage but also on improving ecosystem quality, maintaining habitat connectivity, and strengthening community participation. Policymakers should incorporate ecosystem service valuation into regional development planning to ensure that ecological benefits are considered in economic decision-making. In addition, strengthening livelihood diversification programs and adaptive capacity among coastal communities is necessary to reduce economic dependence on vulnerable ecosystem resources. An integrated ecological-economic management approach is therefore essential to maintain mangrove functions while supporting sustainable regional development.

ADVANCED RESEARCH

Future research should expand the ecological-economic assessment by incorporating more comprehensive biodiversity indicators, including species-level diversity, ecosystem interactions, and long-term ecological monitoring data. Although this study successfully integrates GIS, remote sensing, ecosystem service valuation, and Spatial Analysis using GIS and Remote Sensing, the use of secondary datasets may limit the representation of detailed ecological and socioeconomic dynamics at the local level. Future studies are recommended to combine primary field observations, community-based socioeconomic surveys, and dynamic modeling approaches to better understand how biodiversity changes influence adaptation strategies and long-term economic transformation in coastal regions. Comparative studies across different coastal ecosystems are also needed to validate the applicability of the proposed ecological-economic framework beyond Pamurbaya.

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