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TOTAL ECONOMIC VALUATION OF THE POLLUTED MANGROVE ECOSYSTEM IN BANDAR BAKAU DUMAI

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ABSTRACT

This study aims to calculate the Total Economic Value (TEV) of the polluted mangrove ecosystem in Bandar Bakau Dumai, Riau Province. Mangrove ecosystems provide important ecological and economic services but face serious threats from pollution from industrial activities, domestic waste, and plastic waste. This study uses the Total Economic Value approach, which includes Direct Use Value (DUV), Indirect Use Value (IUV), and Opportunity Value (OV). Data was collected through surveys, interviews with 14 respondents, and secondary data analysis. The results show that the TEV of the mangrove ecosystem is IDR 468,960,000/year, or approximately IDR 15,128,387/ha/year. The DUV component of IDR 147,700,000 is derived from the utilization of shrimp, kedabu fruit juice, and nyirih leaves. The IUV of IDR 320,000,000 reflects services for coastal protection and the provision of marine biota habitat. Meanwhile, the OV of IDR 1,260,000 indicates the community's willingness to pay for conservation. This value confirms that, despite pollution, mangrove ecosystems continue to provide significant economic benefits and should be prioritized in conservation and sustainable management policies.

Keywords: Economic valuation, Mangrove ecosystems, Pollution, Bandar Bakau Dumai

1. INTRODUCTION

The city of Dumai is one of the coastal cities in Riau Province with a strategic position[1]. It is an oil and gas industry city with a large mangrove forest area[2], covering approximately 2,847 ha. This region is known as one of the most important petrochemical industry centers[3] in Indonesia, with the presence of PT Pertamina and various supporting industries. The rapid industrial growth in Dumai has transformed the city into a major economic hub in Riau Province, attracting substantial investment and workforce migration while simultaneously placing increasing pressure on the surrounding natural ecosystems.

The Bandar Bakau area is one of the largest mangrove conservation areas[4] in Dumai City, with great potential as an ecotourism destination[5] but facing pollution pressure from surrounding industrial activities[6]. The coexistence of significant conservation value and intense industrial pressure makes Bandar Bakau a particularly complex and critical case study, where the tension between economic development and ecological preservation is most visibly manifested.

Environmental pollution in the Bandar Bakau Dumai area comes from various sources, mainly petrochemical industrial waste, domestic waste[7], and port activities. The total suspended solids (TSS) concentration in the waters of Bandar Bakau ranges from 180 to 250 mg/L, exceeding the seawater quality standard for biota of 80 mg/L. The total petroleum hydrocarbon (TPH) content in sediments ranges from 15 to 35 mg/kg, indicating significant oil contamination[8]. These pollution levels are particularly alarming given that mangrove ecosystems are inherently sensitive to

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hydrocarbon contamination, which can disrupt root respiration, inhibit seedling recruitment, and reduce the overall biodiversity of associated fauna. The combination of elevated TSS and TPH concentrations creates compounding stressors on the ecosystem, progressively diminishing its capacity to deliver the full range of ecological and economic services it would otherwise provide under unpolluted conditions. If left unaddressed, the cumulative effect of these pollutants' risks crossing ecological thresholds beyond which natural recovery becomes increasingly difficult without active restoration intervention.

Economic valuation of the impact of environmental pollution on mangrove ecosystems is an important instrument[9] in decision-making[10] on environmental management and sustainable policy development[11]. The economic valuation approach can quantify the economic losses[12] due to ecosystem degradation and calculate the potential economic benefits of conservation and restoration[13]. By translating ecological conditions into monetary terms, economic valuation bridges the gap between environmental science and policy, making ecosystem values legible to decision-makers who operate within economic and budgetary frameworks. This approach is particularly relevant in the context of Bandar Bakau, where the visible impacts of pollution on ecosystem conditions must be communicated in terms that justify allocating public resources to conservation and remediation efforts.

Research on the economic valuation of the impact of environmental pollution on ecosystems and the potential of mangrove tourism[14] Bandar Bakau Dumai is highly relevant in providing a scientific basis for sustainable environmental management policy-making[15]. In this regard, the findings from such research serve not only as academic contributions but also as actionable evidence to inform local government regulations, corporate environmental responsibility frameworks, and community-based conservation initiatives aimed at securing the long-term ecological and economic productivity of the Bandar Bakau mangrove ecosystem.

2. RESEARCH METHOD

Time and Place

This study was conducted from September 17-24, 2025, at Bandar Bakau Dumai Tourism in Dumai City, Riau Province.

Methods

The research used a survey method, including field observations and interviews with respondents. Respondents from the community around Bandar Bakau were selected using a census method: all 14 houses located near the mangrove area. Data was collected through questionnaires, interviews, documentation, and secondary data from relevant agencies.

Data Analysis

Total Economic Value (TEV)

To calculate the Total Economic Value using the sum of DUV, IUV, and OV formulas[16].

Direct Use Value (DUV)

$$DUV = DUV1 + DUV2 + DUV3 + DUV4$$

Description:

DUV	=	direct use value
DUV 1	=	direct use value of shrimp
DUV 2	=	direct use value of kedabu fruit juice
DUV 3	=	direct use value of betel leaf shoots

Indirect Use Value (IUV)

$$IUV = IUV\ 1 + IUV\ 2\ (IDR)$$

Description:

IUV	=	indirect use value
IUV 1	=	indirect use value of coastal protection from abrasion
IUV 2	=	indirect use value of providing habitat for marine biota

Option Value (OV) (Pearce & Turner, 1990)[17]

$$OV = \overline{WTP} \times N$$

Description:
OV = option value
$\overline{WTP}$ = Average willingness to pay
N = number of respondents

Total Economic Value (TEV)

TEV = DUV + IUV + OV (IDR)

Description:
TEV = total economic value
DUV = direct use value
IUV = indirect use value
OV = option value

3. RESULT AND DISCUSSION

Bandar Bakau Dumai is a mangrove ecotourism area located on Jalan Nelayan Laut Ujung, Pangkalan Sesai Village, West Dumai District, Dumai City, Riau Province. This area has a mangrove forest ecosystem covering an area of 19 ha. It plays an important role in maintaining coastal environmental balance, such as preventing abrasion and providing habitat for several types of biotas. The mangrove vegetation in this area serves as a natural buffer between land and sea, helping stabilize the shoreline while filtering pollutants that may enter coastal waters. The presence of various mangrove species also supports a rich biodiversity, providing shelter, feeding grounds, and breeding areas for fish, crustaceans, birds, and other coastal organisms that depend on this ecosystem for their survival.

Additionally, Bandar Bakau has been developed as an ecotourism destination managed by the community in collaboration with non-governmental organizations, thereby possessing ecological, social, and economic value. This collaborative management model empowers local communities to take an active role in the conservation and sustainable use of the mangrove ecosystem, while also generating income and livelihood opportunities for those living in the surrounding area. Access to the location is relatively easy as it is not far from the center of Dumai City and is near a main road, making it frequently visited by tourists, students, and researchers for recreational, educational, and research activities, both directly and indirectly. The strategic location of Bandar Bakau makes it an accessible and attractive destination for a wide range of visitors, from families seeking nature-based recreation to academic institutions conducting environmental studies and biodiversity assessments. As a result, the area has grown into an important hub for environmental awareness and community-based conservation efforts in the Dumai region.

Total Economic Value (TEV)

The Total Economic Value (TEV) of the Bandar Bakau Dumai mangrove ecosystem is calculated by summing three main components: Direct Use Value (DUV), Indirect Use Value (IUV), and Option Value (OV). Each of these components captures a different dimension of the economic benefits that the mangrove ecosystem provides, ensuring that both tangible and intangible values are accounted for in the overall assessment. This approach is used to describe the overall economic benefits of the ecosystem, both those that can be directly felt by the community and ecological benefits that are invisible but have significant economic value. By applying the TEV framework, a more comprehensive and accurate picture of the ecosystem's value can be obtained, moving beyond conventional market-based valuation and recognizing the full range of services the mangrove ecosystem provides to local communities and the broader environment. This holistic valuation is essential for informing policy decisions, conservation planning, and sustainable management strategies that seek to balance development needs with the long-term preservation of the Bandar Bakau mangrove ecosystem.

Based on Table 1, the TEV value of the Bandar Bakau Dumai mangrove ecosystem reaches IDR 468,960,000 per year. This value shows that mangrove ecosystems make a significant economic contribution, not only through direct uses such as fisheries and tourism, but also

through environmental services that play an important role in maintaining the sustainability of coastal areas. The magnitude of this TEV value serves as concrete evidence that the mangrove ecosystem is not merely a green area functioning aesthetically, but rather a critical economic and ecological asset that must be preserved for the long-term benefit of coastal communities. The ability of mangroves to simultaneously generate economic value across multiple dimensions, from direct resource extraction to complex ecological services, distinguishes them as one of the most economically productive coastal ecosystems per unit area.

Table 1. Total economic value calculation

No.	Main Component	Sub-Components	Description	Value (IDR/Year)
1.	DUV	DUV 1	Direct value of shrimp	IDR 144,000,000
		DUV 2	Direct utility value of kedabu fruit juice	IDR 1,200,000
		DUV 3	Direct utility value of the Nyirih stem leaf tips	IDR 2,500,000
Total DUV				IDR 147,700,000
2.	IUV	IUV 1	Coastal protection from erosion	IDR 200,000,000
		IUV 2	Providing marine life habitats	IDR 120,000,000
Total IUV				IDR 320,000,000
3.	OV	OV	Average WTP of respondents	IDR 1,260,000
TEV			DUV + IUV + OV	IDR 468,960,000

Direct Use Value (DUV)

Direct use value reflects the economic benefits that communities derive from the direct use of mangrove resources. These benefits are tangible and measurable, as they represent income and goods that community members obtain through their daily interactions with the mangrove ecosystem. The largest component of DUV comes from shrimp fishing (IDR 144,000,000/year). This figure highlights the significant contribution of the mangrove ecosystem to the local economy, particularly for households whose primary source of income depends on the productivity of coastal waters supported by mangrove habitats. This shows that ecosystem-based economic activities are still the mainstay of coastal communities around Bandar Bakau.

The dominance of shrimp fishing in the DUV structure further indicates that the mangrove ecosystem's productivity directly sustains local fishermen's livelihoods. Mangrove forests serve as critical nursery grounds for shrimp and other marine species, providing the food, shelter, and environmental conditions necessary for juvenile organisms to grow and thrive before moving into open waters. This relationship makes mangroves an irreplaceable natural infrastructure within the local economic system, where the quality and extent of mangrove cover are directly proportional to the catch yields the community obtains. Any reduction in mangrove cover or quality would therefore translate almost immediately into reduced fishing productivity and lower household incomes for communities that depend on this sector. The loss of even a small portion of the mangrove area could thus have cascading economic consequences that extend well beyond the fishing industry, affecting food security, household consumption, and the overall economic resilience of the surrounding communities.

The utilization of kedabu fruit and nyirih leaves/stems contributes relatively little to the economy. However, the existence of these two commodities is important as a source of additional income and as an indicator of the potential for local economic development based on non-timber forest products (NTFPs). These natural products represent an underexplored opportunity that, with the right support and investment, could become a meaningful contributor to the local economy over time. If managed and promoted more effectively, the economic value of these commodities could increase alongside the number of visitors and the community's awareness of local products.

Increased visitor numbers, in particular, could open up new market channels for NTFPs, whether through direct sales at the ecotourism site, the development of locally branded products, or integration into educational and cultural programs that highlight the traditional uses of mangrove-derived resources. The development of NTFPs also aligns with the principles of sustainable utilization, enabling communities to derive economic benefits without overexploiting ecosystems. Unlike extractive activities that reduce the stock of natural resources, the careful harvesting of NTFPs can be managed in maintain the ecological integrity of the mangrove forest while still generating consistent economic returns for local communities.

Furthermore, diversifying income sources through NTFPs can serve as an adaptive strategy for coastal communities in the face of fluctuations in fish catches driven by seasonal changes and ecosystem variability. By having multiple streams of income from the ecosystem, communities become less vulnerable to economic shocks and better able to maintain stable livelihoods even during periods when fishing yields are low. The integration of ecotourism activities with NTFPs promotion could further amplify this potential, creating a mutually reinforcing relationship between conservation efforts and local economic development. When visitors are engaged with and educated about the value of mangrove-derived products, it not only generates direct income but also builds broader public support for the conservation of the ecosystem that makes these products possible.

Overall, the total DUV of IDR 147,700,000 per year confirms that the mangrove ecosystem provides real and direct benefits to the welfare of coastal communities. This figure, while representing only one component of the Total Economic Value, is already substantial enough to demonstrate that the Bandar Bakau mangrove ecosystem is not merely an environmental asset but a critical economic resource for the people who live and work in its vicinity. This dependence also indicates that mangrove degradation will directly impact the decline in coastal communities' income. Therefore, mangrove conservation efforts cannot be separated from the community economic empowerment agenda, as both share a mutually reinforcing relationship between ecosystem preservation and human well-being.

A healthy and well-managed mangrove ecosystem is, in essence, a foundation for sustained economic prosperity for coastal communities, and any policy or decision that undermines its integrity will inevitably compromise the livelihoods and welfare of those who depend on it most. Recognizing this interdependence is critical for designing management policies that are both ecologically sound and socially equitable. Conservation strategies that incorporate community participation, equitable benefit-sharing mechanisms, and long-term livelihood planning are therefore essential to ensuring that the mangrove ecosystem of Bandar Bakau continues to deliver its full range of economic and ecological benefits for generations to come.

Indirect Use Value (IUV)

Indirect use value reflects the ecological benefits of mangroves that are not

directly utilized but have significant economic value. The IUV component consists of coastal protection services from abrasion and the provision of marine biota habitats. Unlike DUV, whose benefits can be directly felt and measured by the community, the indirect benefits of mangrove ecosystems are often latent in nature and fully appreciated only when the ecosystem is damaged or lost entirely. This characteristic makes indirect use values particularly important to quantify and communicate, as they are frequently underrepresented in conventional market mechanisms and public decision-making processes.

The value of coastal protection from abrasion is estimated at IDR 200,000,000 per year using the avoided damage cost approach. This value represents the cost of damage that can be avoided due to mangroves as natural coastal protectors. The dense root structure of mangroves plays a role in reducing waves, retaining sediment, and protecting coastal infrastructure and settlements. Without mangroves as a natural shield, the cost of engineering alternative protective infrastructure — such as artificial breakwaters or anti-abrasion retaining walls — would far exceed the estimated value. This makes mangroves a nature-based solution that is economically far more efficient than conventional infrastructure approaches in coastal damage mitigation. The cost-effectiveness of mangroves as natural coastal defense systems strengthens the economic case for their active conservation and rehabilitation, particularly in areas facing increasing coastal erosion.

The value of providing habitats for marine life is estimated at IDR 120,000,000 per year using the production function approach. This value shows the contribution of mangroves to fisheries productivity through their function as nursery grounds and feeding grounds. Although the contribution value used is conservative (5%), the results still show that the quality of the mangrove ecosystem directly affects the sustainability of the fisheries sector. It should be noted that the 5% contribution rate applied in this approach is likely well below the mangrove ecosystem's actual contribution to total fisheries production, given the complexity of ecological interactions within it. This means that the IDR 120,000,000 per year figure is inherently conservative and does not fully reflect the actual benefits mangroves provide to the fisheries sector. A more comprehensive assessment incorporating the full range of species supported by mangrove habitats would almost certainly yield a substantially higher value.

The total indirect use value of IDR 320,000,000 per year confirms that mangrove ecosystem services play an important role in maintaining coastal economic and environmental stability, even though their benefits are not always directly recognized by the community. Notably, the magnitude of the IUV component exceeds that of the DUV, indicating that the ecological benefits of mangrove existence are, in fact, economically more dominant than the physical utilization of its resources. This finding provides a strong argument for prioritizing conservation and restoration approaches in coastal area management policies, as the indirect benefits they generate have a far broader and more enduring economic impact on the welfare of coastal communities and the integrity of surrounding ecosystems.

Option Value (OV)

The option value of IDR 1,260,000 per year was obtained from the community's Willingness to Pay (WTP) approach. This value reflects the community's willingness to preserve the mangrove ecosystem so that its benefits can continue to be felt in the future. OV shows an awareness that mangroves are not only valuable today but also have the potential to provide long-term benefits for future generations. Although the nominal value of OV appears small compared to the DUV and IUV components, this figure carries important social dimensions, as it reflects the community's

subjective perception and valuation of the ecosystem's future. The relatively low WTP value recorded may indicate that community awareness of the importance of mangrove conservation still needs strengthening through environmental education programs, socialization initiatives, and active community involvement in area management.

Nevertheless, the existence of a positive option value, however small, signals that the surrounding community already possesses a foundational awareness of the ecosystem's future value. This awareness can serve as an important form of social capital in driving broader conservation participation. With targeted capacity-building efforts, the willingness to contribute to mangrove preservation could grow substantially over time.

Interpretation of TEV Value

The Total Economic Value (TEV) of IDR468,960,000 per year, or IDR 23,151,613 per ha per year, indicates that the Bandar Bakau Dumai mangrove ecosystem continues to provide significant economic and ecological benefits despite its relatively small area of approximately 31 ha. This value reflects the contribution of various mangrove ecosystem services utilised directly and indirectly by the community, including support for fisheries, coastal protection, and environmental buffer functions[18]. Thus, mangroves continue to play a strategic role in supporting local economic sustainability and coastal ecosystem stability.

The TEV structure, dominated by the IUV component (IDR 320,000,000) compared to DUV (IDR 147,700,000) and OV (IDR 1,260,000), provides an important insight that the true value of the mangrove ecosystem is largely embedded in its indirect ecological services rather than in the direct extraction of its physical resources. This composition implies that management policies focused solely on optimising direct resource utilisation without safeguarding ecological functions would result in the loss of far greater economic value. It further underscores the necessity of an integrated ecosystem-based management approach that balances productive utilization with active conservation of ecological service capacity.

When compared to several research results in other regions, the TEV value obtained is relatively low. This is influenced by the biophysical conditions of the mangrove ecosystem, which has been under long-term pressure from pollution, thereby reducing the quality and capacity of the ecosystem services it provides. In addition, suboptimal area utilisation and the limitations of ecosystem-based management also affect the economic value of mangroves[19].

The long-term anthropogenic pressures on the Bandar Bakau mangrove ecosystem, including industrial pollution from port activities and surrounding settlements, have cumulatively diminished the ecosystem's capacity to deliver optimal services across all valuation dimensions. This condition highlights the urgency of implementing ecosystem rehabilitation programs as a prerequisite for restoring and enhancing the economic value of mangrove services in this area. Nevertheless, the TEV remains relevant because it reflects the actual condition of the ecosystem and the socioeconomic characteristics of the study area, thereby serving as an important basis for sustainable mangrove management and conservation planning. As such, the findings of this study provide a scientifically grounded foundation for policymakers, conservation practitioners, and local communities to collaboratively design strategies that can gradually restore the ecological integrity and economic productivity of the Bandar Bakau Dumai mangrove ecosystem

4. CONCLUSION

The Total Economic Value (TEV) of the polluted mangrove ecosystem in Bandar Bakau Dumai is IDR 468,960,000/year, or IDR 15,128,387/ha/year. This value consists of Direct Use Value (DUV) of IDR

147,700,000 from the utilization of shrimp, kedabu fruit juice, and nyirih leaves; Indirect Use Value (IUV) of IDR 320,000,000 from coastal protection services and the provision of marine biota habitats; and Option Value (OV) of IDR 1,260,000, which indicates the community's willingness to pay for conservation. The significant TEV value confirms that, despite pollution, mangrove ecosystems continue to provide substantial economic and ecological benefits to local communities and play an important role in supporting coastal environmental sustainability. The IUV component, the largest, shows that mangroves' ecological function has a dominant economic value compared to direct utilisation.

The dominance of IUV within the TEV structure highlights that the greatest economic value of the mangrove ecosystem lies not in resource extraction, but in its continuous ecological functions. This calls for a management paradigm shift—from extraction-oriented approaches toward conservation-based strategies that protect the full range of ecosystem services, including coastal protection and marine habitat provisioning, which collectively deliver far greater long-term economic returns for coastal communities.

The relatively low Option Value further reflects limited community awareness of the ecosystem's long-term benefits, underscoring the need for environmental education and participatory conservation programs. Given that the TEV obtained likely represents an underestimation of the ecosystem's true value due to pollution-induced degradation, integrated management strategies addressing pollution control, habitat restoration, and sustainable resource use are urgently needed to safeguard the economic and ecological contributions of the Bandar Bakau Dumai mangrove ecosystem for both present and future generations.

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