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Estimating the Economic Value of Mangrove Ecosystem Benefits from Coastal Rehabilitation Effort in the Coastal Area of Karawang Regency, Indonesia

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ABSTRACT

This study aimed to estimate the economic benefits of the mangrove ecosystem resulting from coastal rehabilitation efforts in the coastal area of Karawang Regency, West Java Province, Indonesia. The estimation results are crucial for convincing stakeholders, including the government, that the budget allocated for coastal rehabilitation will provide significant benefits for human well-being and the sustainability of coastal ecosystems. The study employed an economic valuation analysis method, focusing on the three areas most severely affected by coastal erosion in Karawang Regency. The results showed that the total annual economic benefit from mangrove planting as part of coastal rehabilitation in these areas amounted to IDR 4,257,468,324,946. These findings are intended to support efforts to achieve the Sustainable Development Goals (SDGs).

INTRODUCTION

Using mangrove ecosystems in coastal rehabilitation efforts is one of the coastal protection strategies based on an adaptive, sustainable, multi-functional, and economically feasible ecosystem approach to overcoming coastal erosion **(Gracia *et al.*, 2018; Santoso *et al.*, 2021)**. Efforts to integrate mangrove restoration with coastal rehabilitation are significant for communities and policymakers to reduce the impact of coastal erosion and improve the ecological and socioeconomic quality in coastal areas **(Hashim *et al.*, 2010)**.

As mangrove ecosystems serve as natural barriers against waves and storm surges, their restoration not only mitigates physical damage but also supports fisheries **(Barbier & Strand, 1998)**, provides livelihoods for local communities **(Rönnbäck, 1999)**, enhances biodiversity **(Sungkur *et al.*, 2023; Lovelock *et al.*, 2024; Rahman *et al.*, 2024a)**, and reduces carbon dioxide aiding in climate change mitigation **(Rahman *et al.*,**

2024b), making them a crucial component in comprehensive coastal management strategies. These efforts need to be urgently implemented, consistently in the coastal area of Karawang Regency, West Java Province, as one of the coastal areas in Indonesia that experience severe coastal erosion **(Nopiana *et al.*, 2020a, b, 2020c, 2021, 2023)**.

To follow up these efforts,information is required concerning the economic benefits of the mangrove ecosystem obtained from implementing coastal rehabilitation efforts through mangrove planting when the mangrove area has functioned to form an ecosystem providing its services optimally. This information is essential to convince stakeholders, including the government, that the budget allocated for implementing coastal rehabilitation efforts will benefit both human well-being and the sustainability of coastal ecosystems. A thorough literature review reveals that no studies have estimated the value of the mangrove ecosystem to inform coastal rehabilitation efforts addresing coastal erosion, particularly in the Karawang Regency area. To date, only **Purida and Patria (2020)** have estimated the economic value of the mangrove ecosystem in the Cilamaya Wetan Subdistrict, Karawang Regency, with a focus on conservation program implementation. Therefore, this study aimed to estimate the economic benefits derived from mangrove ecosystem restoration as part of coastal rehabilitation efforts in the Karawang Regency, West Java Province, Indonesia. This study is expected to ultimately assist in achieving the Sustainable Development Goals (SDGs), especially point 14, which focuses on sustainable marine and coastal governance.

MATERIALS AND METHODS

1. Overview of study location

The coastal area of Karawang Regency, West Java Province, encompasses 9 sub-districts and was estimated with a population of over 595 thousand people in 2023. Astronomically, the area is located within the Karawang Regency, between 107^0 02` - $107^0$ 40` East Longitude and 5^0 56`- $6^0$ 34` South Latitude **(Statistics Indonesia, 2024)**. The coastline of this strectches for 73.65km. The land consists of alluvial plains formed by rivers flowing from the inland to the coast. The region is primarily characterized by sloping land with flat terrain, and the elevation fluctuates between 0 and 3 meters above the sea level **(Komarudin, 2013)**.

This study focused on the coastal areas of Karawang Regency that are most severely affected by coastal erosion, as reported by the **Environment, Mining and Energy Office of Karawang Regency (2008)** (Fig. 1). These areas include Cibuaya Beach, Cilebar Beach, and Cilamaya Kulon Beach, which are located across three sub-districts and five villages, as detailed in Table (1).

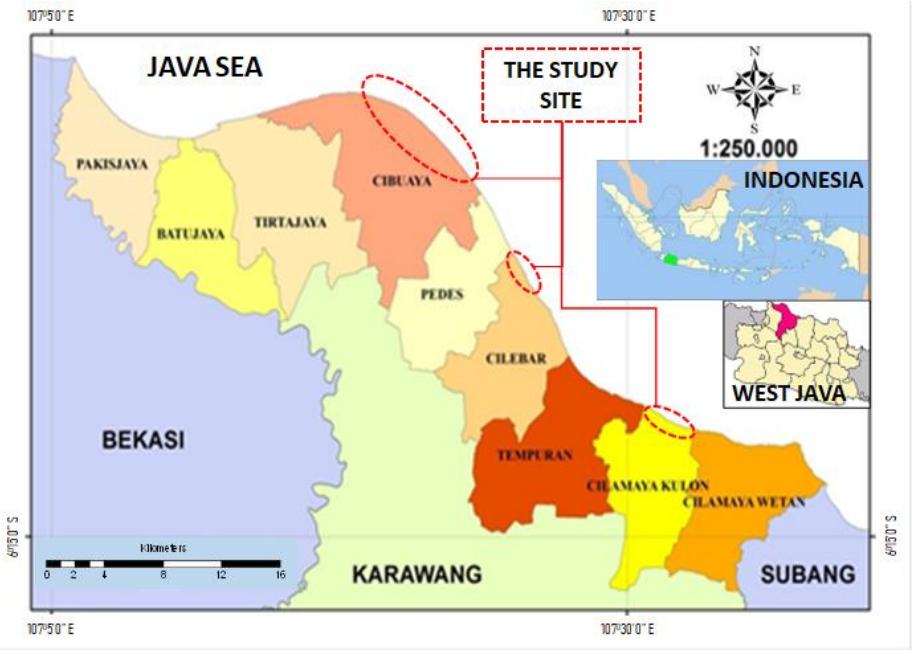

Fig. 1. The study site in the coastal area of Karawang Regency, Indonesia

Table 1. Coverage of coastal areas affected by coastal erosion

No.	Research locations	Coastal areas affected by coastal erosion	
		Sub-district	Village
1.	Cibuaya Beach	Cibuaya	Cemarajaya and Sedari Village
2.	Cilebar Beach	Cilebar	Pusakajaya Utara Village
3.	Cilamaya Kulon Beach	Cilamaya Kulon	Pasirjaya and Sukajaya Village

2. Data and data analysis

The analysis utilizes secondary data to estimate the economic value of ecosystem benefits in the three coastal areas of Karawang Regency. These secondary data weresourced from various research publications, reports from the Karawang Regency Environmental and Sanitation Office, Bank Indonesia, regulations from the Ministry of Public Works and the Ministry of Environment of the Republic of Indonesia, related industries, and other relevant sources. Additionally, primary data were used to complement the analysis.

This study employed an economic valuation analysis method, following the guidelines established by the **Ministry of Environment (2012)**. Various economic valuation techniques were used to calculate each type of economic benefit, as detailed in Table (2).

Table 2. Types of benefits and valuation methods utilized in the study

No.	Type of benefits	Valuation method	Data source and reference
1.	**Supporting services:**		
	- An area for rearing (nursery ground), spawning ground, and scrutinizing for food (feeding ground).	Benefit Transfer	**Purida and Patria (2020)**
	- Biodiversity of mangrove forests	Benefit Transfer	**Ruitenbeek (1992); Lovapinka *et al.* (2014) Lovelock *et al.* (2024) Rahman *et al.* (2024a)**
2.	**Regulating services:**		
	- Oxygen producer	Benefit Transfer	**Rahman *et al.* (2020); National Public Procurement Agency (2024)**
	- Carbon absorber	Benefit Transfer	**Purida and Patria (2020)**
	- A buffer for seawater intrusion processes	Replacement Cost dan Benefit Transfer	**The Ministry of Public Works (2010); Ilmi *et al.* (2017)**
	- Waste treatment	Benefit Transfer	**Salem and Mercer (2012)**
	- Shoreline stabilizer	Benefit Transfer	**Purida and Patria (2020)**
3.	- Sea wind protector	Benefit Transfer	**Khatimah *et al.* (2017)**
	- Flood protector	Benefit Transfer	**Karanja and Saito (2017)**
	Provisioning services:		
	- Producers of wood for building materials	Benefit Transfer	**Fidyansari and Hastuty (2016)**
	- Producers of wood for firewood	Benefit Transfer	**Purida and Patria (2020)**
4.	- Mangrove nurseries	Benefit Transfer	**Kusumastanto *et al.* (1998); Lovapinka *et al.* (2014)**
	- Capture fisheries	Benefit Transfer	**Purida and Patria**

No.	Type of benefits	Valuation method	Data source and reference
			(2020)
	Cultural services:		
	- A natural coastal tourism area	Benefit Transfer	**Salem and Mercer (2012)**
	- A location for education and research	Benefit Transfer	**Baderan (2013)**

This study calculated the economic benefits of mangrove ecosystems into four components of ecosystem services as devined by the **Millenium Ecosystem Assessment (2005**): supporting services, regulating services, provisioning services, and cultural services. The economic value of these benefits was determined based on the area designated for the formation of a mangrove buffer zone to mitigate coastal erosion along the coastline in the three locations most severely affected by coastal erosion (Table 3). The larger the area of the mangrove ecosystem, the greater its capacity to provide ecosystem services, which is reflected in the significant economic value of these benefits.

Table 3. Mangrove buffer zone area

No.	Location	Length of coastline affected by coastal erosion (m)	Width of the green lane (m)	Buffer zone area (ha)
1.	Cibuaya Beach	9,000	500	450
2.	Cilebar Beach	2,500	500	125
3.	Cilamaya Kulon Beach	4,500	500	225

3. Calculation assumptions

The economic value of biodiversity is USD 15 per hectare per year. According to the Jakarta Interbank Spot Dollar Rate (JISDOR) of the Central Bank of Indonesia on August 2, 2024, the exchange rate is IDR 16,234 per USD. The economic value of oxygen production is USD 252.29 per ton per hectare per year, with the price of 6m³ of oxygen being IDR 75,000. The minimum basic drinking water requirement, as per the Ministry of Public Works Regulation, is 60 liters per person per day. The populations of Cibuaya, Cilebar, and Cilamaya Kulon Subdistricts in 2022 were 55,362, 43,914, and 66,597 people, respectively. The economic value of waste processing is USD 5,801 per hectare per year. The economic value of flood protection is USD 275 per hectare per year. The economic value of mangrove nurseries is USD 0.7 per hectare per year. The economic value of coastal nature tourism is USD 1,079 per hectare per year.

The benefit transfer was calculated using the formula of **Fauzi (2015)**:

$$Benefit\ transfer\ coefficient = \left(\frac{The\ United\ States\ per\ capita\ Gross\ Domestic\ Product}{Indonesia's\ per\ capita\ Gross\ Domestic\ Product}\right)^{Income\ elasticity\ coefficient}$$

Where,
income elasticity coefficient is 0.035; the United States per capita Gross Domestic Product in 2023 is USD 81,695.20; Indonesia's per capita Gross Domestic Product in 2023 is USD 4,919.70 **(Statistics Indonesia, 2024b; World Bank Group, 2024)**.
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RESULTS AND DISCUSSION

1. Economic benefits of supporting services

Implementing coastal rehabilitation efforts through mangrove planting is expected to obtain economic benefits from ecosystem services, including supporting services such as nursery grounds, spawning grounds, and feeding grounds, as well as contributing to the biodiversity richness. The total economic benefit value from these supporting services reaches IDR 1,807,222,692 (Table 4). The largest share of this economic benefit is derived from nursery ground, spawning ground, and feeding ground, which are distributed across several coastal areas, totaling IDR 1,630,660,480 per year, or 90.23% of the total economic benefit from supporting services. This value underscores the importance of the mangrove ecosystem as a habitat and feeding area for small fish and other small organisms **(Purida & Patria, 2020)**.

Table 4. The economic benefits of supporting services

No.	Type of benefits	Location	Economic benefit value per year (IDR/year)
1.	An area for rearing (nursery ground), spawning ground, and scrutinizing for food (feeding ground)	- Cibuaya Beach - Cilebar Beach - Cilamaya Kulon Beach	917,246,520 254,790,700 458,623,260
	Subtotal benefits (1)		1,630,660,480
2.	Biodiversity of mangrove forests	- Cibuaya Beach - Cilebar Beach - Cilamaya Kulon Beach	99,316,244 27,587,846 49,658,122
	Subtotal benefits (2)		176,562,212
	Total benefits (1+2)		**1,807,222,692**

Meanwhile, the total economic benefit derived from biodiversity is IDR 176,562,212. This benefit is categorized as an option value, reflecting the potential future value of the mangrove ecosystem, both directly and indirectly **(Fahrudin, 1996; Lovapinka *et al.*, 2014)**.

2. Economic benefits of regulating services

Mangrove ecosystem services derived from implementing various coastal rehabilitation efforts in the form of regulating services include oxygen production, carbon absorption, buffering against seawater intrusion, waste processing, shoreline stabilization, and protection from sea winds and floods. The total annual economic benefit value of these regulating services is IDR 4,238,211,120,990 (Table 5). The high value of these benefits is primarily due to the significant contribution of mangrove ecosystem in buffering seawater intrusion, which account for IDR 1,936,075,263,158 annually, or approximately 45% of the total economic benefits from regulating services. This substantial value highlights the potential losses that communities in Cibuaya, Cilebar, and Cilamaya Kulon Subdistricts could face if a freshwater crisis occurs due to seawater intrusion, leading to increased reliance on bottled drinking or clean water to meet daily needs.

Table 5. The economic benefits of regulating services

No.	Type of benefits	Location	Economic benefit value per year (IDR/year)
1.	Oxygen producer	- Cibuaya Beach	992,399,475,524
		- Cilebar Beach	275,666,520,979
		- Cilamaya Kulon Beach	496,199,737,762
	Subtotal benefits (1)		**1,764,265,734,266**
2.	Carbon absorber	- Cibuaya Beach	242,992,518,750
		- Cilebar Beach	67,497,921,875
		- Cilamaya Kulon Beach	121,496,259,375
	Subtotal benefits (2)		**431,986,700,000**
3.	A buffer for seawater intrusion	- Cibuaya Beach	638,119,894,737
		- Cilebar Beach	510,200,842,105
		- Cilamaya Kulon Beach	787,754,526,316
	Subtotal benefits (3)		**1,936,075,263,158**
4.	Waste treatment	- Cibuaya Beach	38,408,902,139
		- Cilebar Beach	10,669,139,483

No.	Type of benefits	Location	Economic benefit value per year (IDR/year)
		- Cilamaya Kulon Beach	19,204,451,070
	Subtotal benefits (4)		**68,282,492,691**
5.	Shoreline stabilizer	- Cibuaya Beach	10,511,784,000
		- Cilebar Beach	2,919,940,000
		- Cilamaya Kulon Beach	5,255,892,000
	Subtotal benefits (5)		**18,687,616,000**
6.	Sea wind protector	- Cibuaya Beach	8,821,252,350
		- Cilebar Beach	2,450,347,875
		- Cilamaya Kulon Beach	4,410,626,175
	Subtotal benefits (6)		**15,682,226,400**
7.	Flood protector	- Cibuaya Beach	1,817,487,267
		- Cilebar Beach	504,857,574
		- Cilamaya Kulon Beach	908,743,634
	Subtotal benefits (7)		**3,231,088,475**
	Total benefits (1+2+3+4+5+6+7)		**4,238,211,120,990**

The second most significant contribution of mangrove ecosystem benefits is oxygen production, valued at IDR 1,764,265,734,266 annually. **Rahman *et al.* (2020)** reported that the oxygen supply produced by the mangrove ecosystem in the Tallo River, Makassar City, was 252.29 tons of O_2/ha per year. In addition, the benefits of the mangrove ecosystem as a carbon sink contribute the next largest value, with an annual benefit of IDR 431,986,700,000. **Purida and Patria (2020)** reported that the mangrove ecosystem in Karawang Regency's coastal area absorbed 755.75 tons of CO_2 per ha of carbon per year. This value is comparable to the findings of **Rahman (2020)**, who estimated carbon absorption in mangrove stands in West Muna Regency, Southeast Sulawesi, at 776.76 tons of CO_2 per hectare per year, although this study did not estimate the carbon absorption in mangrove mud or substrates.

3. Economic benefits of provisioning services

Implementing coastal rehabilitation through mangrove planting provides several provisioning services, including the production of building wood, firewood, mangrove nurseries, and capture fisheries. The total annual economic benefit from these mangrove ecosystem services is IDR 4,622,603,256 (Table 6). The largest contribution comes from

capture fisheries, with a benefits' value of IDR 4,179,973,442, representing approximately 90% of the total economic benefit value of provisioning services.

In addition to fish, the catch from mangrove areas in some coastal regions of Karawang Regency includes crabs, squid, and shrimp. Fish and crab catches have the highest economic value, with crab fishing in particular being conducted year-round, inpendent of seasonal variations, resulting in relatively high annual catch **(Purida & Patria, 2020)**.

Table 6. The economic benefits of provisioning services

No.	Type of benefits	Location	Economic benefit value per year (IDR/year)
1.	Producers of wood for building materials	- Cibuaya Beach	230,625,000
		- Cilebar Beach	64,062,500
		- Cilamaya Kulon Beach	115,312,500
	Subtotal benefits (1)		**410,000,000**
2.	Producers of wood for firewood	- Cibuaya Beach	13,719,512
		- Cilebar Beach	3,810,976
		- Cilamaya Kulon Beach	6,859,756
	Subtotal benefits (2)		**24,390,244**
3.	Mangrove nurseries	- Cibuaya Beach	4,634,758
		- Cilebar Beach	1,287,433
		- Cilamaya Kulon Beach	2,317,379
	Subtotal benefits (3)		8,239,570
4.	Capture fisheries	- Cibuaya Beach	2,351,235,061
		- Cilebar Beach	653,120,850
		- Cilamaya Kulon Beach	1,175,617,530
	Subtotal benefits (4)		**4,179,973,442**
	Total benefits (1+2+3+4)		**4,622,603,256**

The next most significant economic benefit comes from using mangrove stands as building materials each year, amounting to IDR 410,000,000. According to interviews with the community, mangrove stands are often used to construct anchors for fishing boats, in addition to being used for building houses. Meanwhile, the economic benefit from firewood each year is only IDR 24,390,244. This lower value is related to recent efforts to enforce a prohibition on exploiting coastal resources. The community is apprehensive and fearful of the sanctions imposed by this prohibition. Currently, the

community no longer dares to utilize mangrove trees in coastal rehabilitation areas, except for using dead and dry mangrove trees for purposes such as firewood. However, the need for firewood by coastal communities is increasingly being met by LPG, in line with the government policies promoting energy conversion from kerosene.

4. Economic benefits of cultural services

The mangrove ecosystem services obtained from implementing coastal rehabilitation efforts are cultural services, including the benefits of coastal nature tourism and places for education and research. The total economic benefit value of the mangrove ecosystem services is IDR 12,827,378,009 annually (Table 7). Most of these benefits come from coastal nature tourism, worth IDR 12,700,708,432, or approximately 99% of cultural services' total economic benefit value. The high value of coastal nature tourism indicates the enormous potential for tourism activities in conservation areas (coastal rehabilitation areas), which have natural resources while maintaining the balance of nature **(Yulianda, 2019)**.

Table 7. The economic benefits of cultural services

No.	Type of benefits	Location	Economic benefit value per year (IDR/year)
1.	A natural coastal tourism area -	- Cibuaya Beach	7,144,148,493
		- Cilebar Beach	1,984,485,692
		- Cilamaya Kulon Beach	3,572,074,246
	Subtotal benefits (1)		**12,700,708,432**
2.	A location for education and research	- Cibuaya Beach	71,251,637
		- Cilebar Beach	19,792,121
		- Cilamaya Kulon Beach	35,625,818
	Subtotal benefits (2)		**126,669,576**
	Total benefits (1+2)		**12,827,378,009**

CONCLUSION

The total economic benefit of mangrove planting for coastal rehabilitation in the three areas most severely affected by coastal erosion in the coastal area of Karawang Regency amounts to IDR 4,257,468,324,946 annually. Among these locations, the Cibuaya Beach area offers the greatest potential for mangrove planting, providing the highest economic benefit of IDR 1,943,903,491,993 annually (45.66%). The next largest

potential areas are Cilamaya Kulon and Cilebar Beach, with economic benefits of the mangrove ecosystem of IDR 1,440,646,324,944 (33.84%) and IDR 872,918,508,010 (20.50%) annualy, respectively. The economic benefit of regulating services is the most excellent compared to other mangrove ecosystem services in these three areas. Regulating services provide an annual economic benefit value of IDR 4,238,211,120,990, which constitutes over 99% of the total economic benefit of the mangrove ecosystem in these areas. The high value of these benefits is due to the diverse range services included in this study. Additionally, economic benefits from the mangrove ecosystem also come from cultural, provisioning, and supporting services, with respective values of IDR 12,827,378,009 (0.30%), IDR 4,622,603,256 (0.11%), and IDR 1,807,222,692 (0.04%).

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