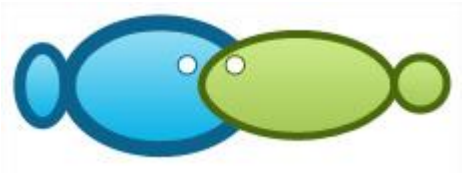

Estimating the economic value of losses due to coastal erosion in the coastal areas of Karawang Regency, West Java, Indonesia

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Abstract. Coastal damage that occurs in the coastal areas of Karawang Regency due to coastal erosion has been concerning. For this reason, coastal rehabilitation efforts must be carried out by requiring a large budget or costs. Various considerations are required to justify allocating the significant costs, including information and data on the economic losses caused by coastal erosion. Thus, this study aims to estimate the value of economic losses on various activities and assets in the coastal areas of Karawang Regency. The data analysis method employed is economic valuation analysis. The study's results show the magnitude of the economic value of losses due to coastal erosion, especially in the most severely affected areas in the coastal areas of Karawang Regency. The losses' economic value consists of the location, activities, assets, and recipients of the losses.
Key Words: coastal damage, coastal rehabilitation, economic valuation methods.

Introduction. Damage to coastal ecosystems due to the use of unplanned and uncontrolled areas for various activities and community interests, directly or indirectly, has been shown to cause problems in people's lives (Van Rijn 2011; Jonah et al 2016). Coastal environmental degradation, including coastal erosion, occurs in many areas in Indonesia (Dianawati & Santosa 2016). This problem is one of the critical issues in the coastal area of Karawang Regency, because the potential impact has threatened the safety and sustainability of coastal communities (Nopiana et al 2020b, 2021). Based on field observations, severe coastal erosion occurs in densely populated residential areas, thus worsening economic and social conditions amid most coastal communities still in poor conditions.

Coastal rehabilitation efforts have been implemented by applying hard structure, soft structure, and a combination of both methods. The hard structure method consists of revetment and breakwater, while the soft structure method consists of coastal vegetation planting, mainly mangroves. Coastal rehabilitation efforts currently being carried out in several areas have begun to produce results by applying methods that focus on planting mangroves, which are supported by the use of hard structure methods (Nopiana et al 2020a). The effort to control coastal erosion is considered economical, effective, and environmentally friendly. Apart from being a coastal protector, from a conservation perspective, planting mangroves will improve ecosystem conditions (Sidik et al 2002; Yulianda et al 2014; Gracia et al 2018; Rangel-Buitrago et al 2018).

However, the coastal rehabilitation efforts implemented so far have proven ineffective in comprehensively addressing the problem of coastal erosion (Nopiana et al 2020a, 2020c, 2023). A considerable budget is needed to deal with coastal erosion and its impacts. Allocating this large budget, among other things, requires data, information, or references regarding the value of economic losses due to coastal erosion in the

Karawang Regency area. Research on calculating the economic value of the coast in the Karawang Regency area has only been carried out by a few researchers who have revealed it according to their respective contexts. Lovapinka et al (2014) estimated the value of economic losses from aquaculture activities by converting mangrove land in Tirtajaya Subdistrict. Purida & Patria (2020) estimated the economic value of the mangrove ecosystem for consideration in implementing a conservation program on the coast of Cilamaya Wetan Subdistrict. Furthermore, Sari (2021) calculated the value of economic losses from the impact of an oil spill off the coast of Karawang. The study aims to estimate the economic value of losses due to coastal erosion on various activities and assets in the coastal areas of Karawang Regency.

Material and Method

Study location and time. The study focused on coastal areas most severely affected by coastal erosion, according to DLHPE Kab. Karawang (2008). The several coastal areas located in three sub-districts and five villages were Cibuaya Beach (Sedari and Cemarajaya Village in Cibuaya Subdistrict), Cilebar Beach (Pusakajaya Utara Village in Cilebar Subdistrict), and Cilamaya Kulon Beach (Pasirjaya and Sukajaya Village in Cilamaya Kulon Subdistrict). This study was conducted from December 2019 to September 2020.

Data collection. The primary data needed in this study are data and information derived from observations and in-depth interviews with relevant stakeholders, including government, business, and community elements. Secondary data are collected through literature searches from various previous studies, Geographic Information System (GIS) analysis results, and other information. In addition, secondary data in the form of exchange rate data is needed to equalize the IDR value with the USD value, sourced from the Jakarta Interbank Spot Dollar Rate (JISDOR) of the Central Bank of Indonesia. The data is based on September 30, 2020, with an IDR 14918 per USD 1 exchange rate.

Analysis. The data analysis method applied in this study is the economic valuation analysis, which refers to the guidelines outlined by the KLH (2012, 2014). Table 1 explains various economic valuation methods applied in this study.

Table 1

Economic valuation methods employed

No	*Affected areas*	*Activities/assets*	*Valuation method*	*Data sources and references*
1	Cibuaya Beach	Aquaculture business	Back of the envelope, replacement cost, fee losses and benefit transfer	Ferryandi et al (2017), Amrial et al (2015), Fisheries Office and Regional Revenue Agency of Karawang Regency, and GIS analysis results
		Mangrove areas	Back of the envelope, replacement cost and benefit transfer	Mangrove farmer groups, and Regional Revenue Agency of Karawang Regency
		Tourism activities	Back of the envelope, fee losses and benefit transfer	Tourism business administrator
		Settlements	Back of the envelope and replacement cost	Public Housing and Residential Areas Office and Regional Revenue Agency of Karawang Regency, and the communities
		Road infrastructure	Back of the envelope, replacement cost and benefit transfer	Pemkab. Majalengka (2018), Karawang Regency Regional Revenue Agency, and observation results
		Electrical infrastructure	Back of the envelope and replacement cost	Badaruddin & Kiswanto (2015), and the State Electricity Company (PLN)

No	Affected areas	Activities/assets	Valuation method	Data sources and references
2	Cilebar Beach	Aquaculture business	Back of the envelope, replacement cost, fee losses and benefit transfer	Amrial et al (2015), Fisheries Office and Regional Revenue Agency of Karawang Regency, GIS analysis results
		Settlements	Back of the envelope, replacement cost and benefit transfer	Property development companies and communities
		Road infrastructure	Back of the envelope, replacement cost and benefit transfer	Pemkab. Majalengka (2018) and observation results
3	Cilamaya Kulon Beach	Aquaculture business	Back of the envelope, replacement cost, fee losses and benefit transfer	Apriliana (2013), 'Ula & Kusnadi (2017), Fisheries Office and Regional Revenue Agency of Karawang Regency, and GIS analysis results
		Tourism activities	Back of the envelope, fee losses and benefit transfer	Tourism business administrator
		Settlements	Back of the envelope, replacement cost and benefit transfer	Property development companies and communities
		Road infrastructure	Back of the envelope, replacement cost and benefit transfer	Pemkab. Majalengka (2018), Karawang Regency Regional Revenue Agency, and observation results

Results and Discussion

Utilization activities are suspected of causing the occurrence of coastal erosion. Coastal erosion is the process of beach retreat from its original position, caused by an imbalance between the supply and capacity of sediment transport. It usually occurs on sandy or muddy sloping beaches (Sulaiman 2017). Coastal erosion is very susceptible to occur in the coastal areas of Karawang Regency because most of the soil characteristics have a clay soil texture. Tides or weak waves very easily carry away the soil with these characteristics because they have a very smooth particle diameter. The distribution of beaches with clay soil texture stretches from Batujaya Beach to Cilamaya Kulon Beach. Only a few beaches have a relatively coarse soil texture, namely Pakisjaya Beach, with a silt soil texture, and Cilamaya Wetan Beach, with a silty sand soil texture (DLHPE Kab. Karawang 2008).

The cause of coastal erosion in the coastal areas of Karawang Regency still needs to be discovered. Based on literature searches, there has yet to be any scientific research discussing the various causes of coastal erosion in the coastal areas of Karawang Regency. It is thought to be caused by, among other things, the high cost of research and the involvement of expertise in various sciences, such as oceanography, hydrography, geodesy, and geophysics (Harsono & Hartoyo 2018).

Coastal erosion occurs due to an imbalance in sediment transport on the coast. This imbalance can occur due to various things, both natural and artificial. Several natural factors that cause coastal erosion include the nature of the coastal land (which is still young and not balanced, where the sediment source is smaller than the sediment lost), land subsidence, transportation to offshore areas, wave climate change, and global sea level rise. In addition, several artificial factors carried out by humans can cause coastal erosion, including the influence of coastal buildings that jut out into the sea, mining of coastal and river materials, relocation of river estuaries, coastal water pollution (which can destroy coral and coastal vegetation), and the influence of the construction of reservoirs upstream due to reduced sediment transport (Sulaiman 2017).

Several coastal resource utilization activities that are suspected of causing coastal erosion in the coastal areas of Karawang Regency include coral and sea sand mining, conversion of mangrove land for aquaculture businesses and development of tourist areas, and the existence of jetties as sources of seawater inlet for aquaculture activities

(Table 2). Prihantono et al (2014) presented research results related to the impact of sea sand mining on coastal erosion on the North Coast of Banten. According to the results of bathymetry measurements, the sea sand mining area has formed a depression on the seabed, which can cause changes in current patterns that encourage coastal erosion. Coral reefs are coastal protectors, which help prevent coastal erosion due to wave energy and ocean currents (Sjafrie 2016).

Table 2

The area of coastal land affected by coastal erosion and accretion

No	*Locations*	*Utilization activities that cause coastal erosion*	*Sources*
1	Cibuaya Beach	Sea sand mining and conversion of mangrove land for aquaculture businesses	Khumaini (2016); observation and interviews with community leaders
2	Cilebar Beach	The existence of the jetties as a source of seawater inlet for aquaculture activities	Rofi & Hutahaean (2012); Nurhadi & Hutahaean (2013); Komarudin (2013)
3	Cilamaya Kulon Beach	Conversion of mangroves for the development of tourist areas and mining of coral and sea sand	Observations and interviews with community leaders

Based on interviews with local community leaders, small-scale coral and sea sand mining was once carried out in the waters of Cilamaya Kulon District in the past. The local community carried out the mining for building materials. However, the community no longer carries out these mining activities. The changes in community behavior, among others, are due to the community's awareness nowadays of the threat of criminal penalties for violators who exploit coastal resources per Law Number 27 of 2007 concerning the Management of Coastal Areas and Small Islands, especially Article 73. In addition, the existence and role of the Community Supervisory Group (Pokmaswas) also supervise and control the utilization of coastal resources.

Illegal sea sand mining activities have also been rampant some time ago, especially in the waters west of the Karawang Regency coast. This exploitation activity aligns with the increasing need for coastal reclamation activities in other areas. The government has never permitted the utilization of sea sand in the area. The potential of sea sand in the waters is targeted by large-scale illegal miners, considering that the availability of sea sand in other waters, such as Banten and Lampung, is almost exhausted. These illegal activities take advantage of the limited supervision carried out by the government and the community (Khumaini 2016).

Similar to coral reef ecosystems, mangrove ecosystems also play a role in protecting the coast from coastal erosion (Sjafrie 2016). The conversion of mangrove land for fish farming and the development of tourism areas carried out in the past has resulted in recent coastal erosion. This condition occurs in Sedari Village, Cibuaya Subdistrict, and Pasirjaya Village, Cilamaya Kulon Subdistrict. The coastal erosion that occurs has damaged aquaculture land, settlements, and the tourism area itself. According to local community leaders, coastal erosion in Tanjungsari Hamlet, Sedari Village, has damaged at least 10 ha of fish farming land. The aquaculture land is directly adjacent to the coastal boundary and is an open pond without mangrove vegetation.

Meanwhile, coastal erosion that occurred in Tanjungbaru Hamlet, Pasirjaya Village, has damaged the infrastructure of the coastal tourism area, such as roads, performance buildings, restaurants, and residences. The massive coastal erosion impacts the number of visitors to the tourist area. Before the coastal tourism area was established, the area was comprised of extensive mangroves. However, in line with the policy of the Karawang Regency Government in the early 2000s, the mangrove area was converted into a beach tourism area. Initially, this tourist area became a tourism icon on

the coast of Karawang Regency. However, over time, tourism activities in the area have faded in line with the increasing intensity of damage due to coastal erosion.

The construction of the jetty in 1987 was carried out to meet the need for saltwater for aquaculture businesses. The coastal building that jutted into the middle of the sea was built along 1500 m. However, over time, coastal erosion occurred along the left coast of the jetty for approximately 3 km. The coast on the right side of the jetty precisely had an accretion of approximately 450 ha (Rofi & Hutahaean 2012; Nurhadi & Hutahaean 2013; Komarudin 2013). Establishing coastal buildings on open beaches can obstruct sediment transport along the coast. As a result, sediment moving from one side of the coastal building will be obstructed, so sedimentation will occur on that side. Conversely, on the other side, the incoming waves form an angle to the coastline, causing a longshore current that can transport sediment. Because this side does not receive sediment supply, the coast experiences erosion (Triatmodjo 2012).

Economic losses due to coastal erosion. The occurrence of coastal erosion in the coastal areas of Karawang Regency has resulted in economic losses due to various activities and assets carried out or owned by the community, government, and private sector. Activities and assets in the Cibuaya Beach area are most affected by coastal erosion. The types of activities and assets often affected by coastal erosion are aquaculture activities, settlements, and road infrastructure (Table 3).

Table 3

Types of losses of activities and assets in the Karawang Regency's coastal areas most severely affected by coastal erosion

No	*Locations*	*Activities/assets that are degraded*	*Sources*
1	Cibuaya beach	Aquaculture, mangrove areas, tourism, settlements, and road and electricity infrastructure	DLHPE Kab. Karawang (2008); BPLH Kab. Karawang (2011); preliminary research results
2	Cilebar beach	Aquaculture, settlements, and road infrastructure	DLHPE Kab. Karawang (2008); BPLH Kab. Karawang (2011); preliminary research results
3	Cilamaya Kulon beach	Aquaculture, tourism, settlements, and road infrastructure	DLHPE Kab. Karawang (2008); BPLH Kab. Karawang (2011); preliminary research results

Coastal erosion has damaged coastal activities and assets in the Cibuaya Beach area, including economic losses to aquaculture businesses, mangrove areas, tourism activities, settlements, and road and electricity infrastructure (Table 3). The following description explains how to calculate the economic loss value of each of these assets and activities.

Aquaculture land is one of the community assets affected by coastal erosion in the Cibuaya Beach area. The calculation of the economic loss value experienced by aquaculture businesses consists of losses due to the loss of land and income. The average price of aquaculture land is based on information obtained from the local community, which aligns with the land price according to the Sales Value of Taxable Object (NJOP) in the village. As a result of coastal erosion, constructing a pond embankment with a length of approximately 2000 m was considered required (Figure 1), with estimated costs referring to Ferryandi et al (2017). The determination of the average profit of aquaculture businesses is based on Amrial et al (2015), which refers to polyculture farming business between tiger prawns and milkfish, which are commonly carried out in the region.

Figure 1. Construction of a pond embankment to withstand coastal erosion aggression.

The results of the GIS analysis show that from 1994 to 2018, the area of pond land lost in the zone reached 113.1 ha, so the total loss of pond land loss reached IDR 22620000000 (equivalent to 1516289 USD) or an annual loss value of IDR 942500000 (equivalent to 63179 USD). Furthermore, building a pond embankment with a height of 1.25 m and a width of 2 m along 2000 m requires a total cost of IDR 235000000 (equivalent to 15753 USD), assuming the construction cost per meter is IDR 117500 (equivalent to 8 USD). In addition, the total income lost from the pond business reached IDR 6863808559 (equivalent to 460102 USD), assuming an average profit for each ha in one of IDR 4855,037 (equivalent to 325 USD) (Amrial et al 2015), and the area of ponds lost gradually amounted to 4.7 ha per year for 24 years. Thus, the total economic loss of the aquaculture business in the Cibuaya Beach area reached IDR 29718808559 (equivalent to 1992144 USD), or an annual economic loss value of IDR 1306825356 (equivalent to 87601 USD) (Table 4).

Table 4

Value of economic losses of aquaculture businesses in the Cibuaya Beach area

Descriptions	*Amounts*
Area of aquaculture land lost (ha) (a)	113.1
Average price of aquaculture land (IDR/ha) (b)	200000000
Total loss of aquaculture land lost (IDR) (c) = (a) x (b)	22620000000
Duration of aquaculture land lost (years) (d)	24
Value of aquaculture land lost per year (IDR/year) (e) = (c) / (d)	942500000
Cost of aquaculture embankment construction with a height of 1.25 m and a width of 2 m (IDR/m) (f)	117500
Length of embankment (m) (g)	2000
Total cost of aquaculture embankment construction (IDR) (h) = (f) x (g)	235000000
Economic life of aquaculture embankment (years) (i)	3
Cost of aquaculture embankment construction per year (IDR) (j) = (h) / (i)	78333333
Average profit of aquaculture business (IDR/ha/year) (k)	4855037
Area of aquaculture land lost per year (ha/year) (l)	4.7
Total lost income from aquaculture business (IDR) (m) = (((d) / 2) x ((l) + (a))) x (k)	6863808559
Total economic loss of aquaculture business (IDR) (n) = (c) + (h) + (m)	29718808559
Value of economic loss of aquaculture business per year (IDR/year)	1306825356

The impact of coastal erosion has damaged the mangrove rehabilitation area in the Cibuaya Beach area. The affected mangrove area is located in Sedari Village, Cibuaya Subdistrict, which is the location for implementing mangrove rehabilitation carried out by PT. Pertamina Hulu Energi Onshore North West Java (PHE ONWJ) in the Orang Tua Asuh Pohon (OTAP) program (Wahyudin et al 2017). Mangrove planting programs often fail, among others, because mangrove planting is not accompanied by the construction of sea wave retaining devices that protect the mangroves that are still in the juvenile category. Hence, the mangroves that have been planted are swept away by waves. This condition is exacerbated by the strong waves that hit the shoreline, especially in certain monsoons.

The calculation of the total economic loss of the mangrove area due to coastal erosion in the Cibuaya Beach area includes the loss of the mangrove rehabilitation area and the cost of making breakwaters. The total economic loss of the mangrove rehabilitation area reached IDR 1734000000 (equivalent to 116235 USD) or an annual loss value of IDR 72250000 (equivalent to 4843 USD). A budget is needed to protect the mangrove rehabilitation area by constructing breakwaters to reduce similar losses in the future. The total cost or budget for building breakwaters reached IDR 2500000000 (equivalent to 167583 USD), or an annual cost of IDR 833333333 (equivalent to 55861 USD). Hence, the total economic loss of the mangrove area was IDR 4234000000 (equivalent to 283818 USD), or an annual loss value of IDR 905583333 (equivalent to 60704 USD) (Table 5).

Table 5

Value of economic losses of mangrove areas in the Cibuaya Beach area

Descriptions	*Amounts*
Mangrove rehabilitation costs (IDR/ha) (a)	55000000
Affected mangrove area (ha) (b)	6.8
Coastal land price (IDR/ha) (c)	200000000
Total loss of mangrove rehabilitation area (IDR) (d) = ((a) + (c)) x (b)	1734000000
Duration of mangrove area affected by coastal erosion (years) (e)	24
Value of loss of mangrove rehabilitation area per year (IDR/year) (f) = (d) / (e)	72250000
Cost of construction and maintenance of breakwater (IDR/m/year) (g)	1000000
Length of coastline for mangrove rehabilitation (m) (h)	2500
Total cost of constructing breakwater (IDR) (i) = (g) x (h)	2500000000
Economic life of breakwater (years) (j)	3
Cost of constructing breakwater per year (IDR/year) (k) = (i) / (j)	833333333
Total economic loss of mangrove area (IDR) (j) = (d) + (i)	4234000000
Value of economic loss of mangrove area per year (IDR/year) (k) = (f) + (k)	905583333

The occurrence of coastal erosion in this area has reduced the ecological value of the coastal ecosystem in the form of a decrease in the aesthetic value of the beach. This decrease in ecological value is indicated by the loss of income from coastal tourism activities, both received by the community and the government (Alexandrakis et al 2015). In order to calculate the value of tourism losses as an impact of coastal erosion, data on past tourism activities in the Cibuaya Beach area is needed. However, due to limited data, the calculation of the loss value is approached by the value of the benefits of coastal tourism activities in the nearest village, namely Sungai Buntu Village, Pedes Subdistrict. Coastal tourism activities in this village are estimated to be equivalent to the same activities at Cibuaya Beach when it still existed.

The value of economic losses from tourism activities calculated includes the value of profits obtained by tourism administrators, traders and the value of retribution paid to the government. The value of economic losses from these activities each year reaches

IDR 5875000000 (equivalent to 393820 USD). For 13 years, the total economic loss from tourism activities in the Cibuaya Beach area was IDR 76375000000 (equivalent to 5119654 USD) (Table 6).

Table 6

Value of economic losses from tourism activities in the Cibuaya Beach area

Descriptions	*Amounts*
Profit value of tourism management per year (IDR/year) (a)	730000000
Average of profit value for traders per business unit per year (IDR/business unit/year) (b)	73000000
Number of traders (business units) (c)	70
Total trader profit per year (IDR/year) (d) = (b) x (c)	5110000000
Value of retribution paid to the government per year (IDR/year) (e)	35000000
Value of economic loss of tourism activities per year (IDR/year) (f) = (a) + (d) + (e)	5875000000
Duration of disruption of tourism activities due to coastal erosion (years) (g)	13
Total economic loss of tourism activities (IDR) (h) = (f) x (g)	76375000000

The Karawang Regency Government implemented a social adaptation policy to deal with the impact of coastal erosion in the Cibuaya Beach area through a community settlement relocation program. This program was attended by 299 families living around the coastline of Cemarajaya Village, Cibuaya Subdistrict. The community settlements were relocated to the upland area in the same village, which was considered safer from coastal erosion. Sekong Hamlet was decided as the location for this relocation program.

The calculation of economic losses includes the cost of relocating community settlements and the cost of renting houses incurred by households affected by coastal erosion until the relocation of settlements is carried out (Table 7).

Table 7

Value of economic losses of settlements in the Cibuaya Beach area

Descriptions	*Amounts*
House construction costs (IDR/m^2) (a)	3055000
House area (m^2/unit) (b)	36
Number of household houses affected by coastal erosion (units) (c)	299
Total cost of housing construction (IDR) (d) = (a) x (b) x (c)	32884020000
Settlement land area (m^2) (e)	30000
Average land price (IDR/m^2) (f)	20000
Land acquisition costs for housing relocation (IDR) (g) = (e) x (f)	1200000000
Total cost of housing relocation (IDR) (h) = (d) + (g)	34084020000
Duration of the construction (years) (i)	3
Cost of housing relocation per year (IDR/year) (j) = (h) / (i)	11361340000
Average of house rental price per unit per year (IDR/unit/year) (k)	6000000
Total cost of housing rental (IDR) (l) = (k) x (c) x (i)	5382000000
Cost of housing rental per year (m) = (l) x (i)	1794000000
Total economic loss of settlement (IDR) (n) = (h) + (l)	39466020000
Value of economic loss of settlement per year (IDR/year) (o) = (j) + (m)	13155340000

The cost of relocation of settlements is calculated based on the settlement relocation program carried out by the Public Housing and Settlement Area Office, which consists of the cost of building settlements and the cost of acquiring land for settlement relocation. The number of houses and heads of families affected reached 299 houses and heads of families. The calculation of the cost of building houses assumes the type of house building is type 36 with a building area of 36 m^2 for each house so that the total cost of building settlements reaches IDR 32884020000 (equivalent to 2204318 USD). The cost of land acquisition is calculated according to the area of land provided by the Karawang Regency Government for the community relocation program of 3 ha, with an average price of coastal land per meter in the village of IDR 20000 (equivalent to 1.34 USD). The average land price is based on the land price in the village, according to the NJOP. The total cost of land acquisition for the settlement relocation program is IDR 1200000000 (equivalent to 80440 USD). Hence, the total cost of settlement relocation reaches IDR 34084020000 (equivalent to 2284758 USD). If the settlement construction period is assumed to be completed in 3 years, then the settlement relocation cost per year is IDR 11361340000 (equivalent to 761586 USD).

Furthermore, the total cost of renting settlements for people affected by coastal erosion while waiting for the relocation process reaches IDR 5382000000 (equivalent to 360772 USD) or IDR 1794000000 (equivalent to 120257 USD) per year. The calculation assumes that the annual house rental cost for each unit in the village area is IDR 6000000 (equivalent to 402 USD). Thus, the total cost of economic losses of settlements due to coastal erosion reaches IDR 39466020000 (equivalent to 2645530 USD), or the value of economic losses per year is IDR 13155340000 (equivalent to 881843 USD).

Coastal erosion in the Cibuaya Beach area has broken off 8 km of the road infrastructure connecting Cemarajaya Village to Sedari Village. This condition makes accessing health and education facilities difficult for people around the area's coastline. Moreover, road access is the lifeblood of production and trade activities in capture and aquaculture fisheries.

The road that connects the two villages in the area is included in the category of primary local roads, which efficiently connect regional and national activity centers with environmental activity centers, inter-local activity centers, or local activity centers with environmental activity centers, and inter-environmental activity centers. According to the road class, the access road is a class III C road with a design speed of at least 20 km per hour and a width of at least 7.5 m (Republic of Indonesia 2004). The total cost of road rehabilitation and reconstruction in the Cibuaya Beach area reached IDR 9951035000 (equivalent to 667049 USD) or an annual economic loss value of IDR 1990207000 (equivalent to 133410 USD) (Table 8). The loss value includes the cost of road construction and the cost of land acquisition for road relocation because there is a broken off road due to coastal erosion as far as 6 km. Road construction is calculated according to hot mix road pavement with a cost per square meter of IDR 323251.25 (equivalent to 21.67 USD) (P.T. Buntara Megah Inti 2020), with an economic life of 5 years (Apriyanto 2008).

The impact of coastal erosion often disrupts the electricity supply, especially for people living on the coastline. The disruption is mainly caused by the collapse of electricity poles due to the structure of the pile foundation being continuously eroded by currents and the impact of waves. This condition raises concerns for the community, especially since the electricity poles are next to the road, which is the primary access for coastal communities in carrying out their economic and social activities.

The value of economic losses from electricity infrastructure is calculated based on the costs borne by the State Electricity Company (PLN) to move electricity poles affected by coastal erosion to a safer place. Based on PLN data, 49 electricity poles are affected by coastal erosion along the 2.45 km area of Cibuaya Beach, especially Cemarajaya Village. The cost of moving electricity poles includes service and material costs. Service costs include dismantling and installing electricity poles, insulators, and low-voltage overhead line conductor cables. The electrical installation materials used are assumed to have old materials from the previously installed electricity network and additional conductor cables caused by the relocation of the electricity poles. Table 9 explains the

cost of moving the affected electricity network as well as the total economic loss of electricity infrastructure reaching IDR 99141945 (equivalent to 6646 USD), or an annual economic loss value of IDR 3965678 (equivalent to 266 USD), based on an economic life of 25 years (Badaruddin & Kiswanto 2015).

Table 8

The value of economic losses of road infrastructure in the Cibuaya Beach area

Descriptions	*Amounts*
Length of rehabilitated road (m) (a)	8000
Width of traffic lane (m) (b)	3.5
Cost of road construction per m^2 (IDR/m) (c)	323251.25
Total cost of road construction (IDR) (d) = (a) x (b) x (c)	9051035000
Width of road body (m) (e)	7.5
Length of new road to be relocated (m) (f)	6000
Land area for road relocation (m^2) (g) = (e) x (f)	45000
Average land price (IDR/m^2) (h)	20000
Cost of land acquisition for road relocation (IDR) (i) = (g) x (h)	900000000
Total loss of road infrastructure (IDR) (j) = (d) + (i)	9951035000
Economic life of road (years) (k)	5
Value of road infrastructure loss per year (IDR/year) (l) = (j) / (k)	1990207000

Table 9

The value of the loss of electricity infrastructure in the Cibuaya Beach area

Descriptions	*Amounts*
Electric pole installation services (IDR/pole) (a)	718816
Electric pole dismantling services (IDR/pole) (b) = 70% x (a)	503171
Insulator installation services on medium voltage cables (IDR/pole) (c)	112800
Installation services for medium voltage overhead line conductor cables (IDR/pole/0.05 km circuit) (d)	546693
Number of affected electric poles (units) (e)	49
Length of affected electric lines (m) (f)	2450
Additional conductor cable requirements (m) (g) = 10% x (f)	245
Conductor cable material price (IDR/m) (h)	9455
Value of conductor cable material (IDR) (i) = (g) x 3 x (h)	6949425
Total loss of electrical infrastructure (IDR) (j) = (((a) + (b) + (c) + (d)) x (e)) + (i)	99141945
Economical life of the electrical network (years) (k)	25
Value of electricity infrastructure losses per year (Rp/year) (l) = (j) / (k)	3965678

Table 3 clarifies the activities and assets that were harmed due to coastal erosion in the Cilebar Beach area, including losses in aquaculture businesses, settlements, and road infrastructure. The calculation of the loss value of each asset and activity can be described as follows.

In line with the development of cultivation technology, in the early 1980s, shrimp farming began to be carried out in Indonesia, including in the Cilebar Coast area. Moreover, in the mid-1980s, the national aquaculture project called Proyek Pandu Tambak Inti Rakyat (PP-TIR) was built in the area. The shrimp farming business reached its peak in the late 1990s. After that period, the productivity of the shrimp farming business decreased, which was in line with the decreasing environmental carrying capacity due to disease attacks and mismanagement (Komarudin 2013). The impact of coastal erosion on shrimp farming land exacerbated this condition.

Based on the results of GIS analysis, from 1994 to 2018, the area of pond land lost reached 38.3 ha, so the total costs of pond land loss reached IDR 7660000000 (equivalent to 513474 USD) or an annual loss of IDR 319166667 (equivalent to 21395 USD) (Table 10). Furthermore, the total income lost from the pond business reached IDR 2324348964 (equivalent to 155808 USD) if the average profit for each ha in one is IDR 4855037 (equivalent to 325 USD) (Amrial et al 2015), and the pond area lost gradually was 1.6 ha per year for 24 years. Thus, the total economic loss of the aquaculture business in the Cilebar Beach area reached IDR 9984348964 (equivalent to 669282 USD), or an annual economic loss of IDR 416014540 (equivalent to 27887 USD).

Table 10

The value of economic losses from aquaculture businesses in the Cilebar Beach area

Descriptions	*Amounts*
Area of aquaculture land lost (ha) (a)	38.3
Average price of aquaculture land (IDR/ha) (b)	200000000
Total loss of aquaculture land lost (IDR) (c) = (a) x (b)	7660000000
Duration of aquaculture land lost (years) (d)	24
Value of aquaculture land lost per year (IDR/year) (e) = (c) / (d)	319166667
Average profit of aquaculture business (IDR/ha/year) (f)	4855037
Area of aquaculture land lost per year (ha/year) (g)	1.6
Total income lost from aquaculture business (IDR) (h) = (((d) / 2) x ((g) + (a))) x (f)	2324348964
Total economic loss of aquaculture business (IDR) (i) = (c) + (h)	9984348964
Value of economic loss of aquaculture business per year (IDR/year) (j) = (e) + ((h) / (d)	416014540

This area's access road, affected by coastal erosion, connects Sungai Buntu Village, Pedes Subdistrict, to PP-TIR, now the Karawang Aquaculture Production Business Service Center (BLUPPB). The length of the road damaged by coastal erosion reaches 2.5 km, located in two hamlets, namely Sukamulya and Sukajadi Hamlets, Pusakajaya Utara Village, Cilebar Subdistrict. The damage to the road infrastructure has been going on for almost 20 years as it was without any visible government efforts to rebuild it. In some road sections, the distance between the shoreline and the road body is very close (a few meters). The total economic loss of road infrastructure due to coastal erosion in the Cilebar Coast area reached IDR 2828448438 (equivalent to 189600 USD) or an annual economic loss of IDR 565689688 (equivalent to 189600 USD) (Table 11).

Activities and assets harmed due to coastal erosion in the Cilamaya Kulon Coastal area include losses in aquaculture businesses, tourism activities, settlements, and road infrastructure (Table 11). The following description explains the calculation of the economic loss value of each of these assets and activities.

Table 11

The value of economic losses of road infrastructure in the Cilebar Beach area

Descriptions	*Amounts*
Length of rehabilitated road (m) (a)	2500
Width of traffic lane (m) (b)	3.5
Cost of road construction per m^2 (IDR/m^2) (c)	323251.25
Total loss of road infrastructure (IDR) (d) = (a) x (b) x (c)	2828448438
Economic life of road (years) (e)	5
Value of road infrastructure loss per year (IDR/year) (f) = (d) / (e)	565689688

Unlike the two previous areas, aquaculture activities in the Cilamaya Kulon Coastal area mainly produce salt and cultivate milkfish, each with one production cycle in one year.

The normal cycle of salt production lasts for 4.5 months, from mid-July to mid-November, when the dry season without rain occurs (Apriliana 2013). Apart from that time, aquaculture activities cultivate milkfish within a six-month production cycle. The technology used in salt production and milkfish cultivation is still relatively traditional, so productivity needs improvement.

The aquaculture land lost due to coastal erosion in this area reached 12.4 ha from 1994 to 2018. The total costs of aquaculture land loss reached IDR 2480000000 (equivalent to 166242 USD) or an annual loss of IDR 103333333 (equivalent to 6927 USD). The average profit of the pond business is obtained from the average profit of salt production and milkfish cultivation each year in 1 ha, each amounting to IDR 1449998 (equivalent to 97 USD) (Apriliana 2013) and IDR 2230000 (equivalent to 149 USD) ('Ula & Kusnadi 2017). Based on these calculations, the total income lost from the aquaculture business reached IDR 570399631 (equivalent to 38236 USD), assuming the aquaculture land lost gradually was 0.5 ha per year for 24 years. Thus, the total economic loss of the aquaculture business in the Cilamaya Kulon Beach area reached IDR 3050399631 (equivalent to 204478 USD), or an annual economic loss value of IDR 127099985 (equivalent to 8520 USD) (Table 12).

Table 12

The value of economic losses of aquaculture businesses in the Cilamaya Kulon Beach area

Descriptions	*Amounts*
Area of aquaculture land lost (ha) (a)	12.4
Average price of aquaculture land (IDR/ha) (b)	200000000
Total loss of aquaculture land lost (IDR) (c) = (a) x (b)	2480000000
Duration of aquaculture land lost (years) (d)	24
Value of aquaculture land lost per year (IDR/year) (e) = (c) / (d)	103333333
Average profit of aquaculture business (IDR/ha/year) (f)	3679998
Area of aquaculture land lost per year (ha/year) (g)	0.5
Total income lost from aquaculture business (IDR) (h) = (((d) / 2) x ((g) + (a))) x (f)	570399631
Total economic loss of aquaculture business (IDR) (i) = (c) + (h)	3050399631
Value of economic loss of aquaculture business per year (IDR/year) (j) = (e) + ((h) / (d)	127099985

Tanjung Baru Beach has been famous for a long time as one of the coastal tourist destinations in the coastal area of Karawang Regency. The tourist area in Tanjung Baru Hamlet, Pasirjaya Village, Cilamaya Kulon Subdistrict, provides tourist facilities in traditional food stalls, entertainment stages, traditional markets, simple accommodations, traditional boat rentals, etc. However, tourism activities in the area have experienced a sharp decline nowadays, as indicated by the lack of visitors. This decline in tourism activities aligns with the damage to the beach and tourist facilities due to coastal erosion (Figure 2).

The calculation of the value of economic losses from tourism activities in the Cilamaya Kulon Beach area follows the previous calculation carried out on the same activity in Cibuaya Beach, including the value of profits obtained by tourism administrators, traders, and the value of retribution paid given to the government. The total economic loss of tourism activities in the Cilamaya Kulon Beach area during the impact of coastal erosion reached IDR 9114000000 (equivalent to 610940 USD), with an annual economic loss value of IDR 1519000000 (equivalent to 101823 USD) (Table 13).

The settlement area most severely affected by coastal erosion in the Cilamaya Kulon Beach area is Kampung Tanjung Baru, Pasirjaya Village (Figure 3). This village, inhabited by around 32 families, is located around a coastline quite remote from its main village. The tidal flood that hit the village exacerbated the coastal erosion.

Figure 2. Damage to the beach and tourist facilities due to coastal erosion at Cilamaya Kulon Beach area.

Table 13
The value of economic losses from tourism activities in the Cilamaya Kulon Beach area

Descriptions	*Amounts*
Value of tourism administrator's profit per year (IDR/year) (a)	35000000
Value of trader's profit per business unit per year (IDR/business unit/year) (b)	73000000
Number of traders (business units) (c)	20
Total trader's profit per year (IDR/year) (d) = (b) x (c)	1460000000
Value of government retribution paid per year (IDR/year) (e)	24000000
Value of economic loss of tourism activities per year (IDR/year) (f) = (a) + (d) + (e)	1519000000
Duration of disruption of tourism activities due to coastal erosion (years) (g)	6
Total economic loss of tourism activities (IDR) (h) = (f) x (g)	9114000000

Figure 3. Damage to settlements area due to coastal erosion at Cilamaya Kulon Beach area.

The calculation of the value of economic losses for settlements was approached through the cost of replacing houses and renting houses while the community was affected by coastal erosion. The cost of purchasing a house was based on the type of building with an area of 36 m^2, with a price according to the benchmark price of housing complexes in neighboring sub-districts. The cost of renting a house per year was considered the same as calculating the value of losses of settlements in Cibuaya Beach (Table 14). The total cost of replacing the house reached IDR 3920000000 (equivalent to 262770 USD), while the total cost of renting the house was IDR 1680000000 (equivalent to 112616 USD). Thus, the total economic loss of settlements in the Pantai Cilamaya Kulon area reached IDR 5600000000 (equivalent to 375385 USD) or an annual economic loss of IDR 560000000 (equivalent to 37539 USD).

Table 14

The value of settlement losses in the Cilamaya Kulon Beach area

Descriptions	*Amounts*
Cost of purchasing a house of 36 m^2 area type (IDR/unit) (a)	140000000
Number of affected household houses (units) (b)	28
Total cost of replacing a house (IDR) (c) = (a) x (b)	3920000000
House rental cost per year (IDR/year) (d)	6000000
Average duration affected by coastal erosion (years) (e)	10
Total cost of renting a house (IDR) (f) = (b) x (d) x (e)	1680000000
Total economic loss of settlement (Rp) (g) = (c) + (f)	5600000000
Economic value of settlement loss per year (Rp/year) (h) = (g) / (e)	560000000

Coastal erosion occurred in Pasirjaya Village, Cilamaya Kulon Subdistrict, and had an impact on the damage to the connecting road to the coastal tourist attractions in the village. This damage to road infrastructure would not have occurred if its construction had paid attention to the minimum coastal boundary regulations following existing regulations, especially Law Number 27 of 2007 concerning the Management of Coastal Areas and Small Islands (Makalew et al 2013). Therefore, in calculating the value of road infrastructure losses, land acquisition costs are required for appropriate road relocation outside the coastal boundary. The total economic loss of road infrastructure in the Cilamaya Kulon Beach area reached IDR 2562758750 (equivalent to 171790 USD) or an annual economic loss value of IDR 512551750 (equivalent to 34358 USD) (Table 15). The calculation assumptions follow those used in calculating the same loss value in the Cibuaya Beach area.

Table 15

The value of economic losses of road infrastructure in the Cilamaya Kulon Beach area

Descriptions	*Amounts*
Length of rehabilitated and relocated road (m) (a)	2000
Width of traffic lane (m) (b)	3.5
Cost of road construction per m2 (IDR/m) (c)	323251.25
Total cost of road construction (IDR) (d) = (a) x (b) x (c)	2262758750
Width of road body (m) (e)	7.5
Land area for road relocation (m^2) (f) = (e) x (a)	15000
Average land price (IDR/m^2) (g)	20000
Land acquisition cost for road relocation (IDR) (h) = (g) x (h)	300000000
Total economic loss of road infrastructure (IDR) (i) = (d) + (i)	2562758750
Economic life of road (years) (j)	5
Value of economic loss of road infrastructure per year (IDR/year) (k) = (j) / (k)	512551750

Furthermore, the detailed description of the economic losses can be summarized based on location, activities, assets, and the loss recipient (Table 16). That illustrates the great

value of the economic losses incurred in the coastal area of Karawang Regency, both in total and in part.

Table 16

The economic losses in the coastal areas of Karawang Regency were the most severe due to coastal erosion

No	*Losses criteria*	*Descriptions*	*Total losses (IDR)*	*Losses value per year (IDR/year)*
1	Based on location	Cibuaya Beach	159844005504	23236921367
		Cilebar Beach	12812797402	981704228
		Cilamaya Kulon Beach	20327158381	2718651735
	Total		192983961287	26937277330
2	Based on activities and assets	Aquaculture business	42753557154	1849939881
		Mangrove area	4234000000	905583333
		Tourist	85489000000	7394000000
		Settlement	45066020000	13715340000
		Road infrastructure	15342242188	3068448438
		Electrical infrastructure	99141945	3965678
	Total		192983961287	26937277330
3	Based on the recipient of the loss	Communities	163009577154	22135279881
		Government	15941242188	3127448438
		Private sector	14033141945	1674549011
	Total		192983961287	26937277330

Conclusions. The economic losses of Karawang Regency's coastal areas most severely affected by coastal erosion reached IDR 192983961287. The annual economic loss value is IDR 26937277330 (Table 16). The coastal area that experienced the most significant economic losses occurred in the Cibuaya Beach area, with total economic losses reaching IDR 159844005504 (equivalent to 10714842 USD) or an annual economic loss value of IDR 23236921367 (equivalent to 1557643 USD). Next is the Cilamaya Kulon and Cilebar Beach areas, each experiencing total economic losses reaching IDR 20327158381 (equivalent to 1362593 USD) and IDR 12812797402 (equivalent to 858882 USD), or an annual economic loss value of IDR 2718651735 (equivalent to 182240 USD) and IDR 981704228 (equivalent to 65807 USD), respectively. The high value of economic losses in the Cibuaya Beach area is due, among other things, to the many activities and assets affected by coastal erosion. It indicates that the coastal rehabilitation efforts implemented in the area have not fully controlled the impact of coastal erosion.

Tourism activities have experienced the most severe impact due to coastal erosion, with total economic losses reaching IDR 85489000000 (equivalent to 5730594 USD), or an annual economic loss of IDR 7394000000 (equivalent to 495643 USD). The cessation of tourism activities has caused a decline in the economic cycle in areas affected by coastal erosion. Settlement assets and aquaculture businesses were also severely impacted, with total economic losses reaching IDR 45066020000 (equivalent to 3020916 USD) and IDR 42753557154 (equivalent to 2865904 USD), respectively, or economic loss values of IDR 13715340000 (equivalent to 919382 USD) and IDR 1849939881 (equivalent to 124007 USD), respectively.

The communities experienced the most remarkable economic losses from the impact of coastal erosion, with total economic losses reaching IDR 163009577154 (equivalent to 10927040 USD) or an annual economic loss value of IDR 22135279881 (equivalent to 1483797 USD). Most of the losses the community experienced came from tourism, residential, and aquaculture activities. The total economic losses experienced by the government and private sector reached IDR 15941242188 (equivalent to 1068591 USD) and IDR 14033141945 (equivalent to 940685 USD), respectively, or the annual

economic losses amounted to IDR 3127448438 (equivalent to 209643 USD) and IDR 1674549011 (equivalent to 112250 USD), respectively. Most losses incurred by the government and private sector came from damage to road and electricity infrastructure.

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