ANALYSIS OF SHORT AND MEDIUM TERM COASTAL ABRASION AND ACCRETION RATES USING GIS IN KARAWANG, WEST JAVA

ANALISIS LAJU ABRASI DAN AKRESI JANGKA PENDEK DAN MENENGAH MENGGUNAKAN APLIKASI GIS DI KARAWANG, JAWA BARAT

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ABSTRAK

Studi berbasis Sistem Informasi Geografis (SIG) telah dilakukan untuk mengukur dampak jangka pendek dan jangka menengah dari abrasi pantai di Karawang, Jawa Barat. Perhitungan jangka pendek memperlihatkan tren yang berbeda-beda di setiap kurun waktu sembilan tahunan. Tren yang seimbang teridentifikasi antara tahun 1988 dan 1997 dimana abrasi dan akresi memiliki laju yang sama 12 ha/tahun. Pada periode antara tahun 1997 dan 2006, akresi mendominasi dengan mengakibatkan munculnya tanah timbul dengan laju 27 ha/tahun, sedangkan erosi hanya mengurangi area pantai dengan laju 2 ha/tahun. Antara tahun 2006 dan 2015, proses abrasi lebih banyak terjadi dengan laju sekira 15 ha/tahun, sedangkan laju akresi hanya 8 ha/tahun. Perhitungan jangka menengah antara tahun 1988 dan 2015 menemukan data bahwa abrasi telah mengakibatkan hilangnya area pantai dengan laju di atas 15 ha/tahun, sedangkan akresi mengakibatkan munculnya tanah timbul dengan laju dua kali lipat dibandingkan laju abrasi pada periode yang sama. Studi ini menampilkan pula skema desain struktur pelindung pantai sebagai opsi alternatif untuk mengurangi dampak erosi pantai di masa yang akan datang dengan menggabungkan metode penanggulangan alami dan buatan.

Kata Kunci: abrasi, akresi, perubahan garis pantai, perlidungan pantai, SIG

ABSTRACT

A GIS-based study was performed to examine the short- and medium-term effects of coastal abrasion in Karawang, West Java. In short-term assessment the trends varied every nine year period. The equal rates were identified between 1988 and 1997 when both abrasion and accretion occurred with rate of 12 ha/year. In the period between 1997 and 2006 the accretion has dominated by causing emerging land of around 27 ha/year, while erosion only displaced 2 ha/year of coastal area. Between 2006 and 2015, further abrasion occurred with rate of approximately 15 ha/year, while accretion rate was only 8 ha/year. Medium-term analysis between 1988 and 2015 suggested that abrasion has affected on area loss with rate of over 15 ha/year, while accretion gave additional land with rate double than abrasion rate at the same period. A brief schematic design of beach protection structures has been provided in the study as alternative option to minimize the future impacts of coastal erosion by incorporating natural and artificial measures.

Keywords: abrasion, accretion, shoreline change, beach protection, GIS

INTRODUCTION

The shoreline is highly dynamics depending mostly on the local environmental conditions (Prasad & Kumar 2014). Many offshore and onshore processes occurred in the area in question and its surroundings can cause the changing of position of such a distinct line between land and sea. One of the important processes is abrasion. Recently, abrasion is categorized as one of the adverse coastal hazards because it may harm coastal habitation and estuarine ecosystem.

Coastal erosion is usually followed by accretion. Erosion and accretion are the predominant factors that affect shoreline change. Shoreline change brings natural processes such as weathering, dissolution, corrosion, and sediment transportation to generate movement in the coastline position, either retreat or advance. Shoreline change, to some extent, is also affected by global issues such as climate change, sea-level rise, as well as occurrences of surge storms and coastal flooding (Paterson et al. 2014).

Abrasion of coasts causes loss of beach volume which acts as one of important inputs on sediment budgeting. Experiments to determine the abrasion rates have been reported in mixed beaches (Hemmingsen 2001) and gravel beaches (Dornbusch et al. 2002). Both studies suggested that rates of abrasion were significantly influenced by location, lithology, residence time in the beach, and degree of weathering. Loss of sediment due to abrasion in either gravel or sandy beach is not easy to quantify, even sediment budget analysis also poorly proves the fact that sediments are being moved to somewhere else (Hicks 1998; Eikaas & Hemmingsen 2006). The sediments can be displaced to the adjacent beaches, into the ocean bottom, or onto the land creating coastal dune (Prasad & Kumar 2014).

Aerial photographs (Jiménez et al. 1997; Fisher & Overton 1994), satellite imagery, topographic maps, and GPS tracking maps (Jonah et al. 2016) are common data sources to display shoreline change at short or less than 10 year period, medium or between 10 and 60 year period, and long or more than 60 year period as well as to identify the change at area scales (Crowell et al. 1993). They also provide suitable information for environmental mapping, land use, storms effects examination, and wave shoaling characteristics (Anfuso & Martínez 2005; Berlanga & Ruiz 2002).

Airborne topographic LiDAR (Light Detection and Ranging) has been used to monitor El Niño erosion and shoreline change (Revell et al. 2002; Sallenger et al. 2003; Stockdon et al. 2002). This remote sensing application is normally utilized to perform detailed 3D surveys, but its utilization is limited due to its high costs (Anfuso & Del Pozo 2009). The use of computer-assisted multivariate analysis, GIS, and numerical models is also valuable on constructing coastal vulnerability maps in every sector throughout the world (Cooper & McLaughlin 1998; Kelly 2000).

Digital Shoreline Analysis System (DSAS), a software extension of ESRI ArcGIS, has been developed to compute rate-of-change statistics from historic shoreline vector data (McLoughlin et al. 2015; Thieler et al. 2009). This tool is useful to quantify shoreline changes in any types of coastal environments like sandy beaches (Esteves et al. 2009; Morton et al. 2005), rocky shoreline cliffs (Jonah et al. 2016; Brooks and Spencer, 2010), coastal wetlands (Gorokhovich & Leiserowiz 2012), estuarine and lagoon boundaries (Cowart et al. 2010; Kuleli 2010). Recently, AMBUR (Analyzing Moving Boundaries Using R) software package provides functions for analyzing and visualizing historical shoreline change along transects as well as for assessing coastal vulnerability (Jackson et al. 2012).

Degree of coastal erosion in Indonesia is relatively high. About 40% of total 80,000 km long of Indonesian shoreline was damaged by coastal erosion (Rahmayanti 2013). It was highly terrifying because about 60% of world (Prasad & Kumar 2014) as well as of Indonesia population live in coastal area. Almost 80% of industrial zones in Indonesia are located in nearshore areas and industrial centers in Java Island are located in northern part of the island that faces Java Sea, popularly well-known as North Coast areas.

Karawang coastal area is located at the north coast region of West Java Province, which in most of its coasts in that region experienced acute abrasion and accretion. It was estimated that coastlines in Karawang had retreat about 50 to 300 meters, which is considered as one of unstable shorelines in Java Island (DLHPE 2008). High degree of coastal erosion has even destroyed public settlements and road construction along the beach, as well as paralyzed agriculture, fisheries, and many economical public activities (Fauzie 2016). This terrific condition is worsened by other environmental hazards that occur continuously in the area. Therefore, the study is aimed to identify the area, length, and annual rate of coastal abrasion and accretion occurred in Karawang coastal area using Geographic Information System (GIS) as a tools. The study also provides alternative scheme and design useful for local authorities and city planners at all levels of government to mitigate the continuous effects of coastal erosion hazard.

METHODS

The Study Area: The Regency of Karawang is located at the northern part of West Java Province, Republic of Indonesia. Geographically, it lies between 107° 02′ and 107° 40′ East Longitude and between 5° 56′ and 6° 34′ South Latitude. Java Sea faces on the north-side of the region with 73.65 km long shoreline. Total extent of the region is

1,753.27 sq.km or 175,327 ha with 2,250,120 populations in 2014, which makes the population density as large as 1,283 per sq.km (BPS 2015). There are totally 30 sub-regencies and 309 villages, but only 9 sub-regencies and 100 villages are located by the coast, which are populated by more than half million people or 24.7% of the total regency population. Nine sub-regencies in this study are divided into four zones namely Zone I, Zone II, Zone III, and Zone IV. See Figure 1 for details. Zone I has three sub-regencies, while others each has two sub-regencies. See Table 1 for details. Nineteen villages are precisely located along the shoreline where most of the villagers live and work as fishermen in either marine capture or nearshore fishery.

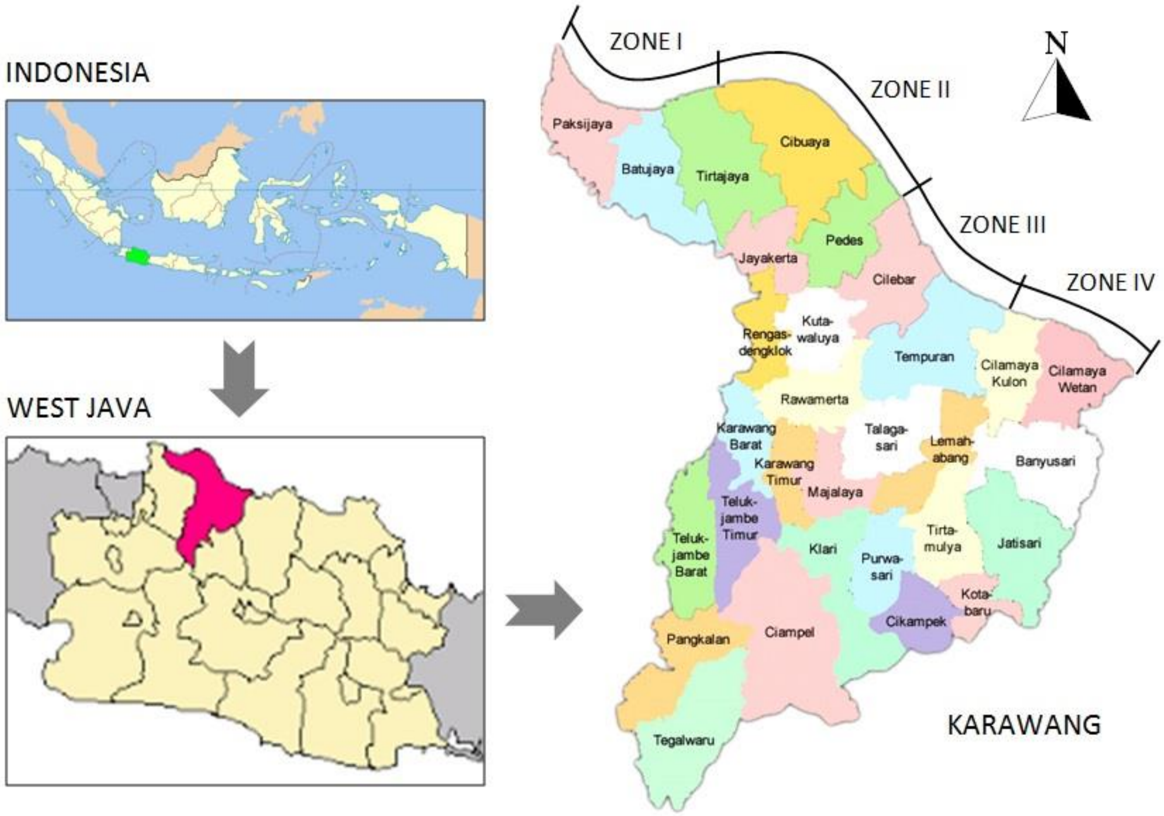

Figure 1. Location of four sampling zones in Karawang Regency, West Java Province, Indonesia

Erosion has taken many areas of littoral lands such as aquaculture and agriculture lands, and damaged lots of public infrastructures such as housings and roads. Almost all beaches in Karawang face high threat of coastal erosion, particularly in the northmost villages of Pakisjaya, Batujaya, Tirtajaya, Cibuaya, Pedes, Cilebar, Tempuran, Cilamaya Kulon, and Cilamaya Wetan sub-regency. High abrasion impacts have been identified in Cibuaya and Cilebar beach. A significant number of public habitation, shops, restaurants, and religious buildings in both beaches were destroyed by abrasion. Asphalt roadway that lies along Cibuaya coast has been damaged since few years ago. Many buildings were abandoned because of the retreat of the coastline. See Figure 2 for details. Coastline retreat has become major threats to Karawang regency. The occurrence of coastal erosion is always accompanied by accretion. Sediments scrapped by rip currents from eroded beach are transported gradually by longshore currents, in accordance with wind and wave direction, which cause land accretion in other beaches. The observation of Karawang coastline revealed that Cibuaya beach is the most impacted beach by coastal erosion, while accretion effect was found higher in Cilamaya Wetan beach than in any other beaches. Cilebar beach has been experiencing a high degree of both abrasion and accretion.

Table 1. Classification of coastal zones in Karawang

Zone	Sub-regency	Nearshore Village	Area (ha)	Coastline length (km)
I	Pakisjaya	Tanjungpakis	1,828	11.25
	Batujaya	Segarjaya	1,926	2.25
	Tirtajaya	Tambaksari	2,475	6.00
		Sub Total	6,229	19.50
II	Cibuaya	Sedari	2,518	12.00
		Cemarajaya	1,031	8.00
	Pedes	Sungaibuntu	996	4.50
		Sub Total	4,545	24.50
III	Cilebar	Pusakajaya Utara	866	6.30
		Mekarpohaci	872	2.25
	Tempuran	Tanjungjaya	1,008	1.70
		Sumberjaya	686	0.60
		Cikuntul	547	0.80
		Tempuran	479	1.00
		Ciparagejaya	480	2.50
		Sub Total	4,938	15.15
IV	Cilamaya Kulon	Pasirjaya	862	0.90
		Sukajaya	620	3.60
	Cilamaya Wetan	Sukakerta	732	1.00
		Rawagempol Kulon	548	1.70
		Muarabaru	738	4.50
		Muara	1,569	2.80
		Sub Total	5,369	14.50
		Total	21,081	73.65

Sources: DLHPE 2008; BPS 2015.

Methods: Satellite imagery was used to calculate the loss or addition of extent of coastal zone due to abrasion and accretion. The images were available in U.S. Geological Survey website (USGS Landsat Archive 2015). They were captured by Landsat satellite on Path 122/Row 064 at the coordinates of 05º 47′ 10″ South Latitude and 107º 12′ 59″ East Longitude. Four satellite imageries were used in this study, particularly on August 20, 1988; September 9, 1997; June 27, 2006; and July 6, 2015. See Figure 3 for details. The 2006 and 2015 imageries were acquired from Landsat-7, while the remaining two were obtained from Landsat-5. The imageries were processed and compiled to calculate the area affected by coastal abrasion and accretion as well as their rates during short-term of 9-year period and medium-term of 27-year period.

The maps were processed using MapInfo Professional 11. The process was started by registering all satellite images by means of digital topography maps. The Karawang topography maps were obtained from the Geospatial Information Agency. Registration of topography maps are required to draw the administrative boundaries, including the regency and sub-regency boundaries. The maps provide geographical coordinates in latitude and longitude. Thus, the registration of satellite imageries was completed by inputting point coordinates identified on the topography maps into the software database. Registration of satellite images was done by inputting the coordinates of four corners (NW, NE, SE and SW) of each image into the software. The coordinates of the corners were taken from the metadata of the imageries provided by USGS in their data set attribute files obtained in the same package while downloading the imageries.

The registration process is considerably important in this study because a small misinterpretation would displace the shoreline from its exact location, which would create major errors on the measurement of the area of the coastal land that are affected by abrasion and/or accretion. The possibility to acquire good registration result is increased by using higher number of registered objects. Therefore, it is required to identify important landmarks as many as possible in this process, such as river branches, river mouth to the sea, river mouth to the lakes, etc. The registration errors in this study were kept at maximum of 1 to 2 pixels to avoid further miscalculation.

Digitizing procedures were taken to draw the coastline and administrative boundaries after completing the registration of the images. The temporal shoreline changes were clearly visualized by overlaying the satellite images of 1988, 1997, 2006 and 2015. Abrasion and accretion were defined by calculating extent of areas between coastlines from different years using tools provided by the software. Coastline retreat and advance were identified by dividing that area by length of shoreline affected by abrasion or accretion in order to measure how far shoreline had changed after a specific period of time. Abrasion and accretion rates per year were calculated by dividing abrasion and accretion area by time period of analysis. The unit of rates used in this assessment is presented in either hectare per year or meter per year.

Figure 2. Site view of Karawang coastal area at (a) Zone I (b) Zone II (c) Zone III (d) Zone IV
Source: DLHPE 2008.

RESULTS AND DISCUSSION

Estimation of Abrasion and Accretion Rates: Figure 4 clearly describes the changes of Karawang shoreline between 1988 and 2015. The abrasion process is indicated by the retreat of coastline to the landward direction, whereas accretion process is highlighted by the advance movement of coastline to the seaward direction. The figure shows that abrasion mainly occurred in west-side of Zone I, north-side of Zone II, and few portions of north- and south-side of Zone III, while accretion mainly took place in middle area of Zone III and eastern area of Zone IV. Abrasion and accretion processes also occurred in eastern part of Zone I, whereas east-coast of Zone II and west-coast of Zone IV are relatively stable with only minor changes.

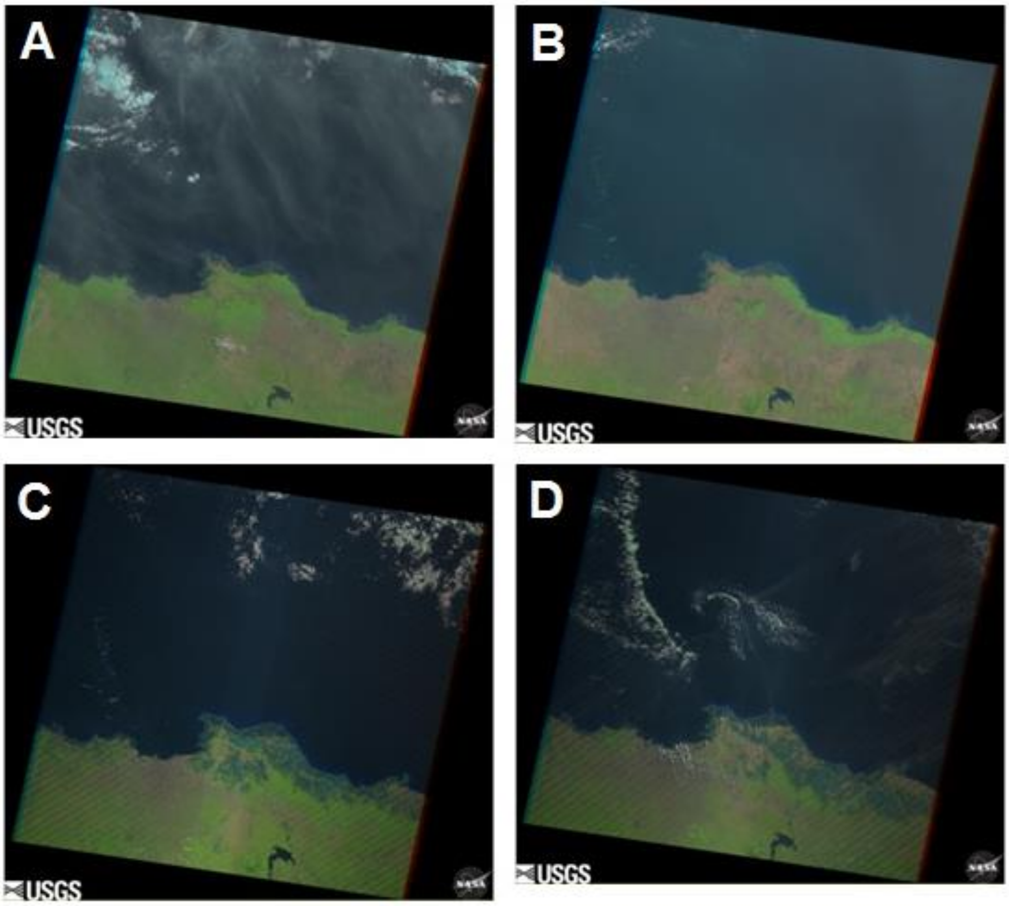

Figure 3. Satellite imagery of Karawang area captured by Landsat in (a) 1988 (b) 1997 (c) 2006 (d) 2015
Source: USGS Landsat Archive 2015.

Karawang coastal area had been experiencing different trends of coastal processes in short-term of every nine year period. See Table 2 for details. High degree of abrasion occurred predominantly in Zone II and Zone III in the first period of the study between 1988 and 1996, while, on the other hand, Zone III experienced high degree of accretion, particularly in the eastern part of Cilebar sub-regency. Zone II had lost 150 ha of its coastal area because of wave-forced abrasion, which is the largest in Karawang. The longest shoreline affected by abrasion was 20-km long and it was located in Zone II, while the highest coastline retreat of approximately 100 m is identified in Zone III, particularly because a high degree of area loss occurred in only a short shoreline. Having a high degree of land loss, Zone II and Zone III had higher abrasion rate than it of the other zones. Zone I had a balanced sediment budget due to the extent of area loss and addition in this period is almost the same. Zone IV had the same area loss with Zone I between 1988 and 1997, but Zone IV had acquired more land of approximately 100 ha, which occurred in Cilamaya Wetan beach if compared to Zone I with only about 50 ha of additional land. Similar with Zone III, Zone IV had the highest coastline advancement and, thus, highest accretion rate.

Second period of study between 1997 and 2006 shows domination of accretion process rather than abrasion. Land addition was higher in all study sites compared to land loss. The shoreline affected by accretion was also longer than the one affected by abrasion. The average distance of coastline advancement was also higher than of coastline retreat. Therefore, the calculated accretion rate in the second nine-year period was higher than the abrasion rate. Beach protection efforts have been taken by local or national authorities in this period to reduce the coastal erosion effects by plantation of mangrove colonies and construction of hard physical structures such as groin, revetment, breakwater, and jetty. The evidences were seen in the existence of revetments, jetty and breakwater structures as well as newly-planted mangrove colonies in almost all sites, even though the actual construction date was not exactly known. In spite of large number of accreted shoreland, however, the abrasion process still occurred within this period as Zone I and Zone II were still experiencing land loss and eroded shoreline which were higher than land loss of the other zones.

The unpleasant trends of abrasion were recurring in the third period of the study between 2006 and 2015. A large extent of area has been lost due to abrasion, particularly in Zone I and Zone II with some considerable portions of Zone III and Zone IV as well. Western part of Zone I and northern part of Zone II experienced the highest impacts. More than 150 hectares of lands in each zone had disappeared during that period and more than 10 km of each shoreline were affected. The longest retreat was identified in Zone I, which approximately reached up to 125 m, although other zones were also experiencing a longer coastline retreat than it of the period before. The abrasion rate per year was higher in Zone I and Zone II, approximately 5 ha/year in area basis or 4 m/year in width basis. In spite of this unfavorable condition, accretion process can still be found in Karawang coasts during this period such as in the middle area of Zone III and eastern area of Zone IV as there was 80 ha additional land extent in each zone, making these zones to have higher accretion rate of about 3 ha/year or 3 m/year than it of the other zones.

Trends on short-term abrasion and accretion rates are quite different in each period. First period shows balanced rate of 12 ha/year of both abrasion and accretion. Second period had different trend when accretion rate reached almost 27 ha/year, but abrasion rate only accounted for about 2 ha/year. Another different trend was found in the third period as abrasion rate was higher, approximately 15 ha/year, compared to accretion rate at the same period that was 8 ha/year. Therefore, short-term rates cannot be used as a basis to predict shoreline change at longer time scale, because there were various factors that affected shoreline change in each period, for example the existence of beach protection facilities. Without beach protection efforts, it is predicted that the future abrasion and accretion rate will be equal. On the other hand, with beach protection efforts, the accretion rate will increase, although it will last only for less than a decade.

In medium-term of 27-year period the abrasion occurred mostly in west-side of Karawang coastal zones, while accretion took place more in east-side zones. See Figure 5 for details. Area in Zone II had lost 186 ha land extent from 1988 to 2015, followed by Zone I and Zone III with land loss of approximately 100 ha each, while Zone IV had lost only 24 ha of its coastal land. Conversely, accretion or land addition was considerably high in Zone IV that accounted for more than 400 ha, followed by Zone III that was over 300 ha, Zone I that was over 80 ha, and Zone II that was over 50 ha. See Figure 5a for details. More than 100 m of coastline retreat occurred in the three coastal zones namely Zone I, Zone II, and Zone III during 27 years, with the higher retreat was identified in Zone III. Zone IV had only retreated 76 m in that period. See Figure 5b for details. Shoreline in Zone III and Zone IV had considerably advanced seaward to more than 300 m in almost three decades, while a slight advancement was identified in other areas.

The trends on abrasion and accretion rate were calculated in area-based unit of hectare per year, which shows different results compared to measurement in width-based unit of meter per year. See Figure 6 for details. By using the area-based unit, the highest abrasion rate occurred in Zone II that accounted for more than 6 ha/year, followed by Zone I and Zone III, each had abrasion rate of approximately 3 ha/year, and Zone IV had the lowest abrasion rate. See Figure 6a for details. Different trend was found on the measurement of abrasion rate using width-based unit. Zone III had the highest erosion rate that accounted for more than 5 m/year, followed by Zone II and Zone I, each had rate of 4 m/year. Zone IV still had the lowest erosion rate among others. See Figure 6b for details. The different trend between area-based and width-based unit is due to Zone II had longer shoreline affected by abrasion, which was 15.56 km or 64% of total shoreline length in that zone compared to Zone III that had only 6.37 km or 42%. See Figure 7 for details. This leads to the further retreat of coastline in Zone III as compared to Zone II even though the land loss in the latter was higher than it of the former area.

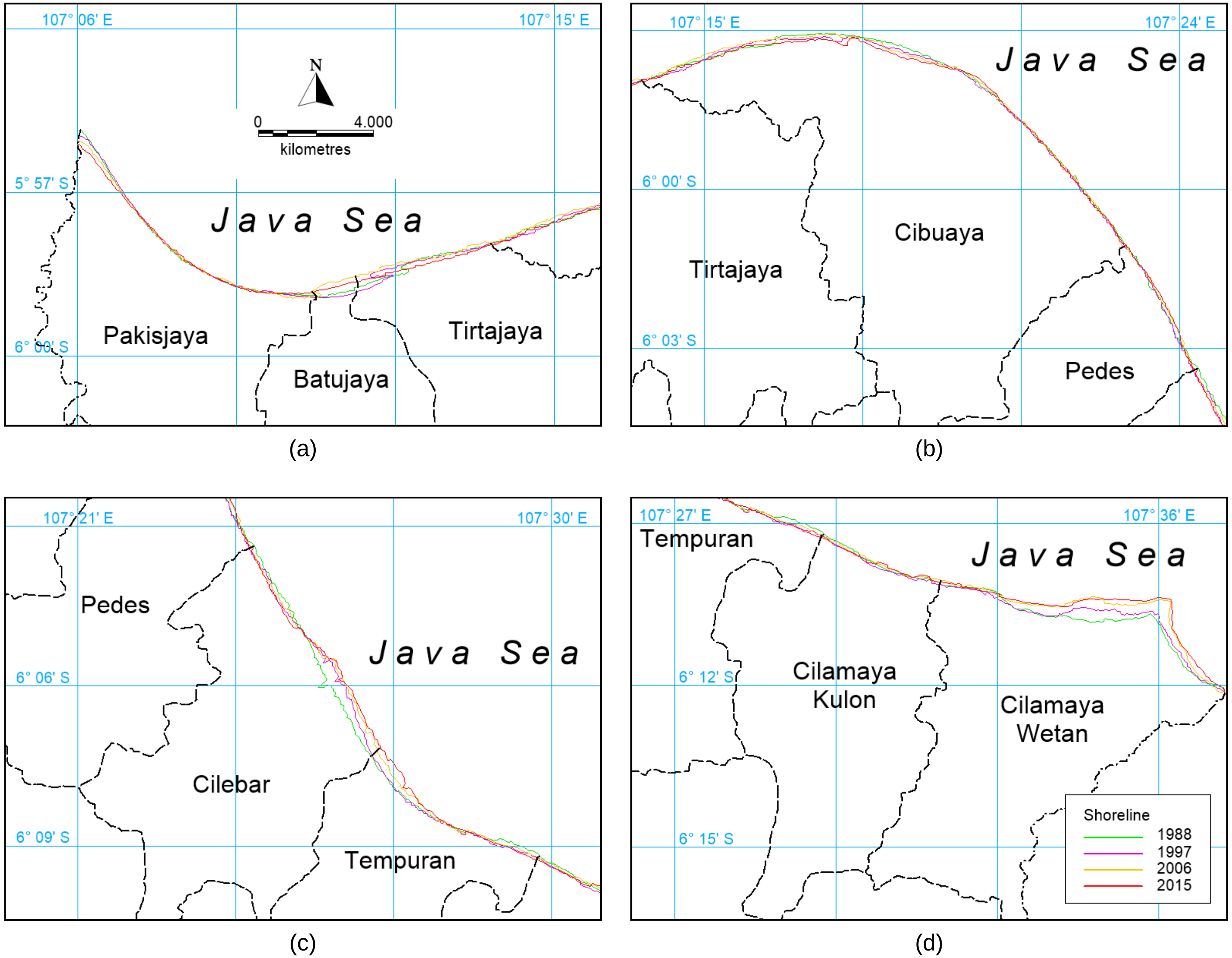

Figure 4. Shoreline changes from 1988 to 2015 at Karawang coastal area (a) Zone I (b) Zone II (c) Zone III (d) Zone IV

Table 2.Trend in Karawang coastal area during 9-year (short-term) and 27-year (medium-term) period

Zone	Area (ha) affected by		Area balance (ha)	Shoreline length (km) affected by		Coastline retreat (m)	Coastline advance (m)	Abrasion rate		Accretion rate	
	abrasion	accretion		abrasion	accretion			(ha/year)	(m/year)	(ha/year)	(m/year)
1988 to 1997:											
I	-51.11	48.18	-2.93	9.04	7.71	-56.55	62.45	-1.89	-2.09	1.78	2.31
II	-148.31	33.10	-115.21	20.83	4.13	-71.21	80.14	-5.49	-2.64	1.23	2.97
III	-94.45	133.30	38.85	9.29	6.13	-101.64	217.46	-3.50	-3.76	4.94	8.05
IV	-55.14	113.20	58.06	8.46	7.17	-65.18	157.88	-2.04	-2.41	4.19	5.85
Total	-349.01	327.78	-21.23	47.62	25.14			-12.93		12.14	
1997 to 2006:											
I	-42.96	144.27	101.31	7.84	8.92	-54.78	161.80	-1.59	-2.03	5.34	5.99
II	-18.70	145.33	126.62	4.06	20.82	-46.04	69.82	-0.69	-1.71	5.38	2.59
III	-8.82	147.90	139.08	2.44	13.13	-36.15	112.64	-0.33	-1.34	5.48	4.17
IV	-2.50	291.10	288.60	0.54	15.44	-46.25	188.54	-0.09	-1.71	10.78	6.98
Total	-72.98	728.59	655.61	14.88	58.30			-2.70		26.98	
2006 to 2015:											
I	-152.73	32.25	-120.47	12.19	4.70	-125.29	68.60	-5.66	-4.64	1.19	2.54
II	-168.22	23.81	-144.41	17.23	6.94	-97.65	34.32	-6.23	-3.62	0.88	1.27
III	-46.87	84.37	37.51	6.49	8.83	-72.27	95.57	-1.74	-2.68	3.12	3.54
IV	-35.48	85.67	50.19	5.59	10.53	-63.52	81.36	-1.31	-2.35	3.17	3.01
Total	-403.30	226.11	-177.19	41.49	31.00			-14.94		8.37	
1988 to 2015:											
I	-107.48	84.22	-23.26	8.63	8.16	-124.50	103.15	-3.98	-4.61	3.12	3.82
II	-186.25	56.64	-129.61	15.56	8.93	-119.72	63.42	-6.90	-4.43	2.10	2.35
III	-100.56	315.41	214.85	6.37	8.84	-157.86	356.79	-3.72	-5.85	11.68	13.21
IV	-24.23	422.32	398.09	3.18	12.24	-76.15	344.89	-0.90	-2.82	15.64	12.77
Total	-418.52	878.59	460.07	33.74	38.18			-15.50		32.54	

Abrasion and accretion rates (in meter/year) are calculated perpendicular to shoreline in landward and seaward direction, respectively. Minus signs represent loss or retreat.

Such differences could also be identified in the case of accretion. Based on area-based measurement, Zone IV had the highest accretion rate that accounted for more than 15 ha/year, which was higher than Zone III with rate of 11 ha/yr, followed by Zone I and Zone II with the approximate rates of 3 and 2 ha/year, respectively. On the other hand, based on width-based measurement, Zone III has been calculated to have the highest accretion rate accounted for about 13 m/year, slightly higher than it of Zone IV with rate of 12 m/year, followed by Zone I and Zone II that each has rate of below 4 m/year. The reason was still the same, because Zone IV has longer shoreline affected by accretion, which was approximately 12.24 km or 79% of total shoreline length in that zone compared to Zone III that shoreline length was only 8.84 km or 58%. Therefore, average coastline advancement was slightly higher in Zone III, even though Zone IV had lost more area compared to Zone III or any other coastal zones.

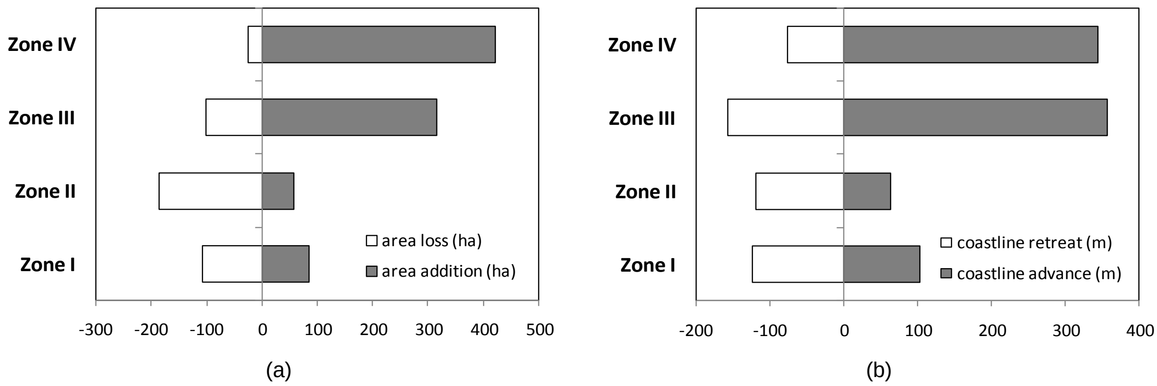

Figure 5. Changes in Karawang coastal area from 1998 to 2015 including (a) area loss and addition (b) coastline retreat and advance

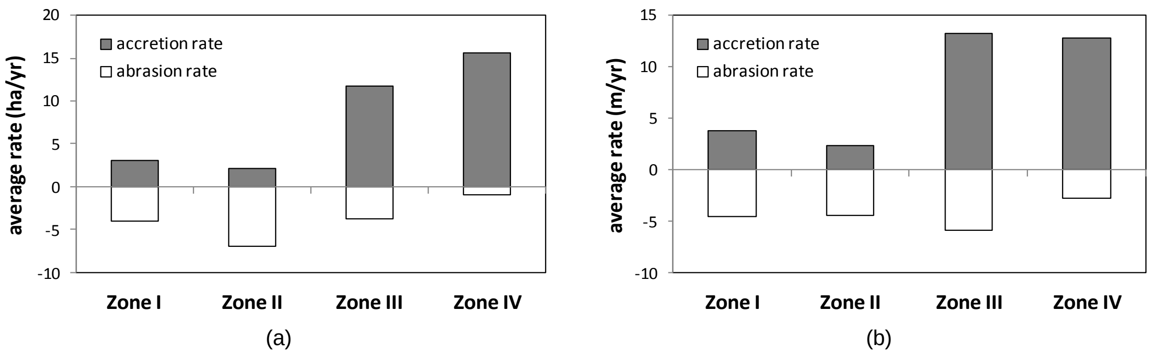

Figure 6. Medium-term rates of coastal abrasion and accretion measured in (a) hectare per year (b) meter per year

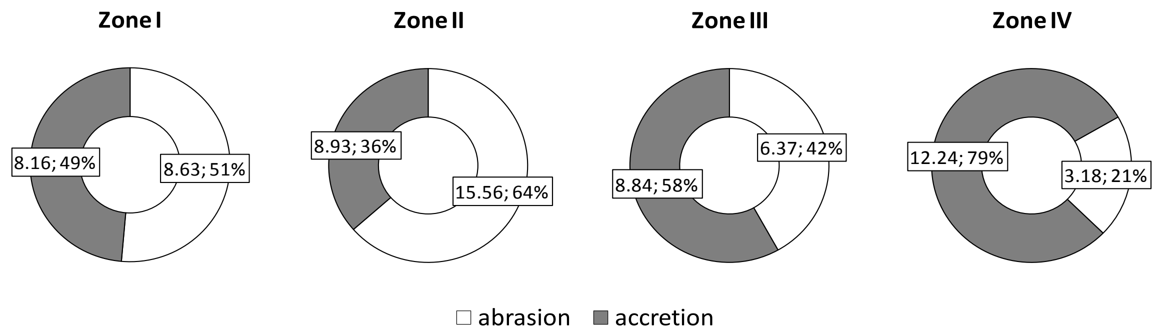

Figure 7. Length of shoreline affected by erosion and accretion comparing from 1998 to 2015 conditions. Units are written in km; %.

Total abrasion rate for all coastal zone in Karawang was 15.5 ha/year, while total accretion rate was 32.5 ha/year. Average width-based abrasion rate for the whole Karawang coastline was 4.59 m/year, and average width-based accretion rate was 8.52 m/year. Total area loss in Karawang due to abrasion was 418 ha, while, on the other hand, it had also additional land of 878 ha. Therefore, in general, Karawang had acquired more coastal lands due to sedimentation that added 460 ha of land extent after almost three decades, mainly in Zone III and Zone IV. Although accretion rate was still higher than abrasion rate and sediment budget showed a surplus status, however, due to its adverse effects to the surrounding environment and daily livelihood, concern on coastal erosion has still been growing, particularly at local governments and even at a higher administrative level. Further efforts are expected to be done to prevent and minimize further impacts of abrasion, particularly the undesirable land loss and the continuous coastline retreat.

Alternative Solution: Basically, nature provides its own beach protection structure against erosion including sand dunes in sandy beaches and mangrove plants in loamy beaches. Besides supplying sand materials, sand dunes can act as wave breaker as well as protector from surge storm along the beach. Mangroves can also break sea-wave energy. These coastal indigenous plants are valuable on beach development process, particularly on protecting soil stability and preventing soil erosion. This is because sediments carried by longshore currents can be trapped and stored in between their respiring roots that have tentacle-like structure. In the area in which natural protections are no longer existed, coastal erosion can be minimized artificially by constructing jetty, groin, breakwater, revetment, or sea-wall. Combination of both natural and artificial measures can be good alternative solution to cope with coastal erosion that combines a durable physical structure and further leads to the sustainable ecosystem conservation.

Different types of hard protection structures have been constructed several years ago in Karawang coasts. Nonetheless, they were localized in only few areas and covered only a short distance. The existing structures are breakwaters in Tirtajaya, revetments in Pedes, and groin in Cilebar sub-regency. Many other hazard-prone areas are still not protected, such as Cibuaya and Pakisjaya sub-regency. Some of the existing structures provide a single protection scheme only, such as jetty, groin, breakwater, revetment, or mangrove colonies, and some others provide a combination of either man-made structures or man-made and natural structure such as groin and breakwater, revetment and mangroves, or breakwater and mangroves.

Structures like jetty, groin, and revetment are suitable for loamy beaches like in Karawang, which protects the land from loss of materials due to erosion by rip and longshore currents. Meanwhile, breakwater is the appropriate structure to minimize the surge storm effects and to reclaim mangrove and other coastal ecosystem that has already damaged. Therefore, combination of different structures like revetment-mangroves-breakwater (BPLH 2011) can be a better alternative and act as a stronger protection to prevent abrasion in Karawang coasts as well as to restore coastal habitats. See Figure 8 for details.

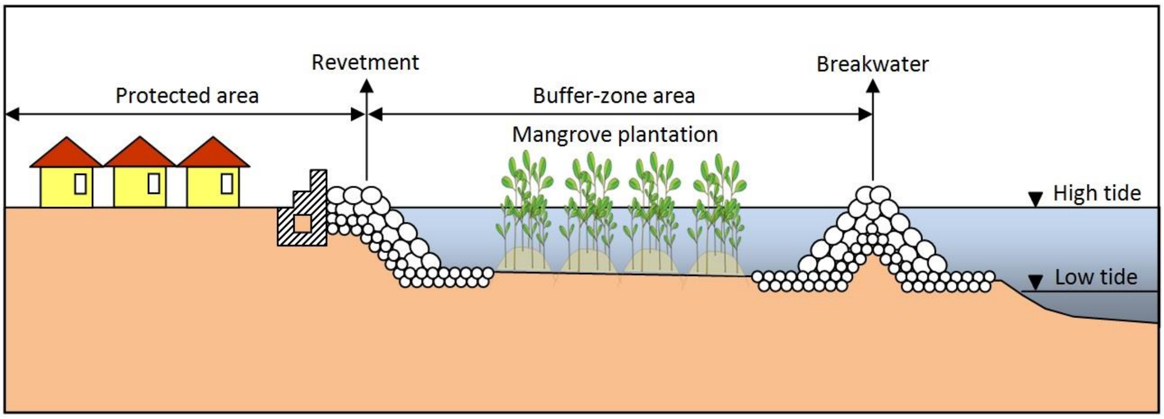

Figure 8. Combination design of revetment-mangroves-breakwater structures

A proposed plan for the locations of beach protection structure installation has been prepared. See Figure 9 for details. The plan examines the actual condition of Karawang coasts in each zone including beach shape and angle, land topography and bathymetry, annual windrose, surge storm and tide trends, existence of river mouths, littoral ecosystem characteristics, available public facilities like roadways, river ports and tourism beach, and the existing beach protection structures. Acute eroded area and nearshore roadways should be protected by combination scheme of breakwater, mangroves, revetment, and groin or jetty. Breakwater without revetment is preferable for tourism beach. A combination of jetty and revetment is suitable to support river ports and river mouths.

Cost estimation to build hard physical structures is provided in Table 3. It depends mainly on the basal depth of the ocean below sea level that may vary at different coastal zones. Width and slope of the structure are given for every standard construction, while project cost is given at the basis of 1-meter long. However, length of the structures may vary, depending on the actual needs in the field and on the budget available for funding the project.

Figure 9. Proposed plan for constructing abrasion protection structures in Karawang location

Table 3. Cost estimation for the construction of revetment and breakwater structures

Depth (m)	Width (m)	Slope	Revetment			Breakwater		
			Vol./1 m (m^3)	Unit Price (IDR)	Cost/1 m (IDR)	Vol./1 m (m^3)	Unit Price (IDR)	Cost/1 m (IDR)
1	2	1.5	2.1	215,000	451,500	3.5	250,000	875,000
2	2	1.5	6.0	215,000	1,290,000	10.0	250,000	2,500,000
3	2	1.5	11.7	215,000	2,515,500	19.5	250,000	4,875,000
4	2	1.5	19.2	215,000	4,128,000	32.0	250,000	8,000,000
5	2	1.5	28.5	215,000	6,127,500	47.5	250,000	11,875,000

Source: BPLH 2011.

CONCLUSION

Coastal abrasion plays a vital role on ecosystem and economic disruption in North Coast area of West Java, particularly in Karawang Regency. Loss of shoreland, retreat of coastline, and damage of nearshore fisheries, public housing, and road infrastructures are the strong evidences found in Karawang coastal area. Assessment using GIS tools found that coastline retreat has been happening since 1988, especially in the northern zones. Short-term study of every nine-year period explained the instability of Karawang shoreline. First period from 1988 to 1997 shows balanced trend between abrasion and accretion. In second period from 1997 to 2006 the shoreline change was mainly affected by accretion that caused emerging land in all zones, while, in the third period from 2006 to 2015 abrasion frequently took place, which caused a large extent of shoreland to be disappeared in Zone I and Zone II. Medium-term study of 27-year period from 1988 to 2015 suggested that abrasion still occur in serious condition, particularly in Zone I, Zone II, and Zone III, while accretion was found higher mostly in Zone IV and some parts of Zone III.

The unconformity trend in the magnitude of erosion and accretion rates is still found either in short-term or medium-term analyses, because the changes in shoreline position may be influenced by various factors. However, the hazard of coastal abrasion must be mitigated immediately to avoid the continuous effects to the coastal community and littoral ecosystem. With particular physical and meteorological characteristics of Karawang beaches and provision of several public facilities along the coasts, a combination of mangrove plantation and hard protection structures can be a better and sustainable option for preventing the higher impacts of coastal erosion in Karawang in the future.

ACKNOWLEDGEMENT

Author is thankful to CV. Hermacon Utama Consultant for providing information and consultancy regarding annual windrose, surge storm and tide trends in Karawang region as well as for collecting experts' advices on designing coastal protection structures and their cost estimation.

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