Utilizing digital shoreline spatial analysis to analyze and predict shoreline change in Karimunjawa and Kemujan Islands by 2033 and 2043

[1]Alfa B. P. Trinida, [2]Max R. Muskananfola, [2]Suryanti Suryanti

[1] Aquatic Resources Management Master Program, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia; [2] Department of Aquatic Resources, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia. Corresponding author: A. B. P. Trinida, alfabagas214@gmail.com; alfabagasputra14@students.undip.ac.id

Abstract. Karimunjawa and Kemujan islands are located in Karimunjawa National Park, Jepara, Central Java Province, Indonesia. There is currently no specific program that addresses erosion and accretion in Karimunjawa National Park. This research was performed to analyze the rate of shoreline change that occured from 2008 to 2023 and predict shoreline change in 2033 and 2043. This research also provides an overview of the current patterns and types of sediments at the research site as supporting data. Shoreline data were obtained by extracting multitemporal satellite imagery from Landsat 7, Landsat 8, and Sentinel 1. The shoreline data were analyzed using ArcGIS 10.8 software and the Digital Shoreline Analysis System (DSAS) to calculate erosion and accretion rates. The results showed that the average rates of erosion on Karimunjawa Island and Kemujan Island during 2008 to 2023 was 15.08 m and 0.99 m per year respectively. Meanwhile, the accretion rates on Karimunjawa Island and Kemujan Island were -12.29 m and -0.85 m per year respectively. The shoreline is preditected to reach the highest erosion rate for the periods 2023, 2033 and 2043 of -6.132 m per year with an average rate of -0.979 m per year. The highest accretion rate is predicted to reach 13.229 m per year with an average rate of 1.174 m per year.

Key Words: accretion, coastal, erosion, forecast, sediment.

Introduction. More than 80% of the global shoreline change is caused by coastal erosion due to rapid development in coastal areas (Sam & Gurugnanam 2022; Daswin Ebenezer & Kumar 2023). Most of the coastal problems are caused by human activities and increased land use in coastal areas (Muskananfola et al 2022b). As an archipelagic country with long shorelines, Indonesia also experiences issues related to shoreline changes. The hydrodynamic process is a natural factor that affects the change in shoreline, in addition to land use (Suryanti & Ruswahyuni 2014; Muskananfola et al 2022a; Safitri et al 2019).

Karimunjawa National Park in Indonesia consists of 27 islands, with two major islands being the center of community activities, namely Karimunjawa Island and Kemujan Island. The dynamic global oceanographic conditions and exploration of land and other resources on Karimunjawa Island and Kemujan Island pose problems related to coastal erosion and accretion. In an interview, the management of Karimunjawa National Park Office explained that there is no program that addresses the erosion and accretion problems in Karimunjawa National Park, especially on Karimunjawa Island and Kemujan Island. Therefore, temporal monitoring to the shorelines should be performed to minimize the negative impacts of erosion and accretion, and to predict shoreline change for the next 10 and 20 years.

Shoreline mapping can be carried out using remote sensing method to gain detailed data of the shoreline condition (Co et al 2021; Thangaperumal et al 2020). Spatial monitoring of the temporal shoreline supports the analysis and prediction of areas that are vulnerable to erosion and accretion (Daswin Ebenezer & Kumar 2023). The analysis was conducted using ArcGIS 10.8 application and DSAS (Digital Shoreline Analysis System) application to measure the Net Shoreline Movement (NSM), End Point Rate (EPR) and Linear Regression Rate (LRR) values. DSAS method enables statistical calculation of the rate of change of shorelines from historical shoreline positions (Muskananfola et al 2020; Muhammad & Mardiatno 2023).

In this research, the erosion and accretion rates that occurred from 2008 to 2023 in the site were analyzed. Meanwhile, the prediction of shoreline changes for the next 10 and 20 years were analyzed based on the combination of satellite imagery data, i.e. Landsat 7, Landsat 8, and Sentinel 1 multispectral satellites, which provided more detailed SAR-based imagery for shoreline analysis. In addition, the current conditions and types of sediment can be analyzed as supporting data (Ali & Razak 2022). The results of this research are expected to provide insights to the optimization of coastal management strategies in Karimunjawa National Park and mitigate coastal areas by reducing the negative impacts of erosion and accretion.

Material and Method

Description of the study sites. The research was conducted in Karimunjawa District, Jepara Regency, Central Java, along the shoreline of Karimunjawa Island and Kemujan Island. Karimunjawa Island is located at 5°49'33'' - 5°48'23'' south latitude; 110°24'34'' - 110°28'37'' east longitude with an area of 4302.5 ha. Meanwhile, Kemujan Island is located at 5°46'24'' - 5°59'16'' south latitude; 110°26'55'' - 110°26'38'' east longitude with an area of 1501.5 ha (Sya'rani & Suryanto 2006) as shown in Figure 1.

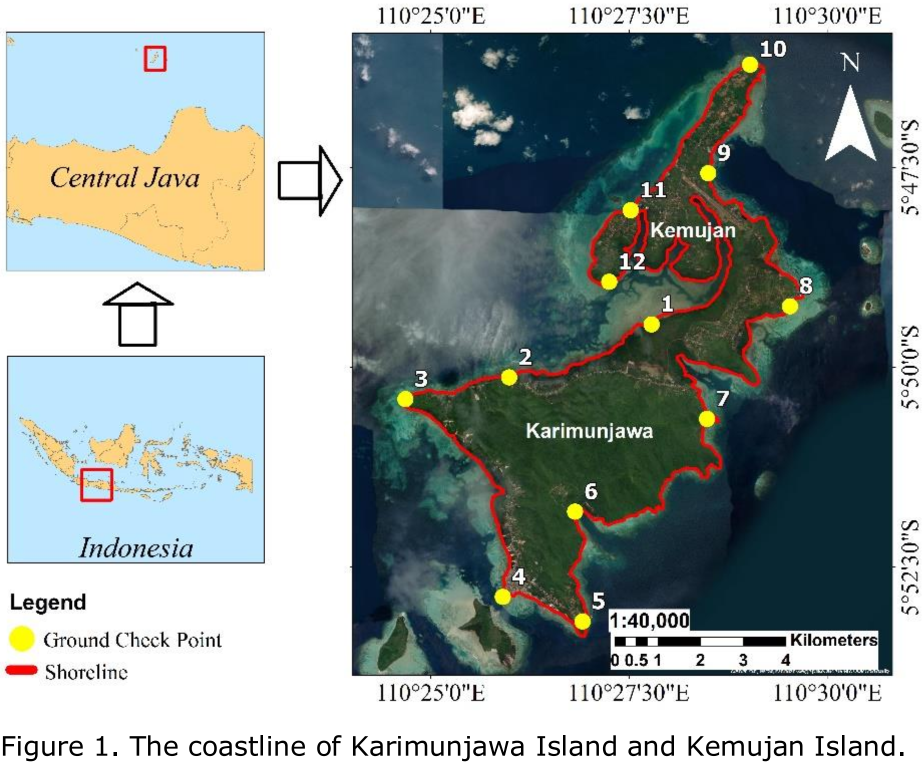

Figure 1. The coastline of Karimunjawa Island and Kemujan Island.

The ground check point was located at 12 points representing the north, east, south and west areas on each island. The ground check point allows the examination of the actual condition of the area experiencing erosion and accretion by analyzing the sediment samples.

Data collection and data analysis. The data were taken from Landsat 7, Landsat 8, and Sentinel 1 satellite imagery with a span of every 3 years in 2008, 2011, 2014, 2017, 2020, 2023. The 3-year interval was considered appropriate in representing the rates of change of the shoreline. The data were analyzed using a geographic information system application, ArcGIS 10.8. The analysis of the satellite imagery data included the process of separating water and land using the Normalized Difference Water Index (NDWI) formula using green bands and near infra red (NIR) bands on the Landsat 7 and Landsat 8 satellites. On the Sentinel 1 satellite, the separation of water and land is presented in the results of the Urban SAR combination available at https://apps.sentinel-hub.com/eo-browser.

After separating water and land, the shoreline was digitized, a baseline was created, and the shoreline was overlaid from 2008 to 2023. The transect lines and quantitative spatial data were measured using DSAS application. The rates of erosion and accretion were measured based on NSM and EPR values resulted from DSAS analysis using the following equations:

$$NSM = D1 - D2$$

where D1 is the youngest shoreline distance, and D2 is the oldest shoreline range. NSM is a calculation on DSAS that measures the distance of shoreline change between the oldest shoreline and the youngest shoreline.

$$EPR = (D1 - D2)/(t1 - t2)$$

where D1 is the youngest shoreline distance, D2 is the oldest shoreline range, t1 is the youngest year of the shoreline and t2 is the oldest year of the shoreline. EPR is used to calculate the rate of change of a shoreline by dividing the NSM value by the difference in shoreline time.

This study also analyzed current patterns and sediment types using data that were obtained from the Marine Copernicus website and analyzed using the Seadas and ArcGIS applications. Ocean currents underwent interpolation analysis to determine the direction and speed of currents around the island. Soil laboratory analysis were conducted based on the sediment samples collected from 12 survey points. Samples were first dried using an oven and analyzed using the dry method with a sieve shaker. The data were then calculated using the GRADISTAT application to determine the type and size of sediment at each point.

Erosion and accretion prediction data were obtained based on EPR and LRR values. LRR was used for statistical analysis which was determined by plotting the position of the shoreline intersection (distance from baseline) versus time (years) and calculating the linear regression equation. The data outcome were reanalyzed using the filter tool available in DSAS estimate the position of shorelines 10 or 20 years in the future (Himmelstoss et al 2021; Ahammed & Pandey 2022; Sam & Gurugnanam 2022).

Results. Karimunjawa Island and Kemujan Island serve multiple purposes beyond residential settlements, accommodating a variety of activities including agriculture, plantations, tourism, and aquaculture. Research conducted in these areas yielded the following findings.

Characteristics of the research location. In addition, the coastal area has several important ecosystems such as mangrove, seagrass, and coral reef ecosystems. The results of the sediment texture analysis can be seen in the Figure 2.

Based on the results of ground checks and interviews with the community, the beaches along the coastal areas of Karimunjawa Island and Kemujan Island predominantly have sandy beaches and some beaches have sediments in the form of rocks and coral fragments. The current patterns on Karimunjawa Island and Kemujan Island represent the seasons in Indonesia. The data were collected in February during the western season, in May during the first transitional season, in August during the eastern season, and in November during the second transitional season. The data of the current velocity can be classified into three categories: very fast (> 1 m s^{-1}), fast (0.5-1 m s^{-1}), moderate (0.2-0.5 m s^{-1}), slow (0.1-0.2 m s^{-1}), and very slow (< 0.1 m s^{-1}) (Risnawati et al 2019). The results of the current pattern analysis are presented in Figure 3.

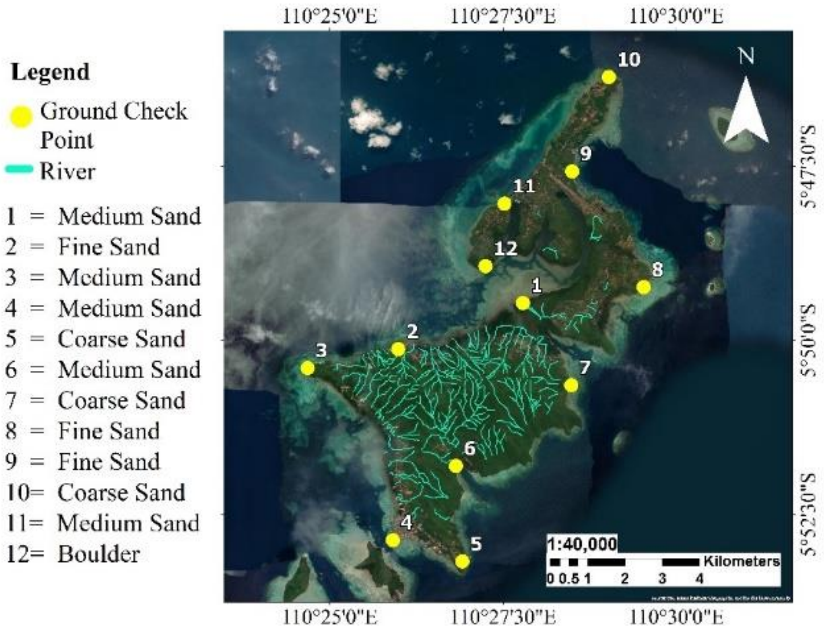

Figure 2. Sediment type distribution.

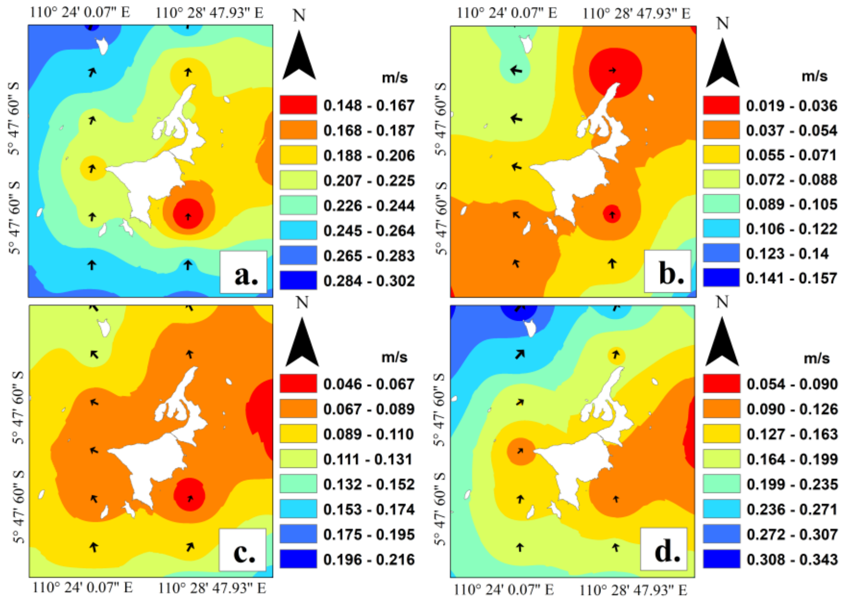

Figure 3. The current pattern of Karimunjawa Island and Kemujan Island: (a) February, (b) May, (c) August, (d) November.

During the western wind season in February, the current moves predominantly from the southwest to the northeast at 0.148-0.302 m s^{-1}, with an average speed of 0.244 m s^{-1} (moderate speed). During the first transition period in May, the current moves predominantly from southeast to west at a slow speed of 0.019-0.157 m s^{-1} with an average of 0.064 m s^{-1}. At the beginning of the first transitional season, the current around Karimunjawa Island and Kemujan Island began to decrease in speed and change in direction towards the eastern season.

In the eastern season period in August, the current mainly moves slowly from southeast to northwest at a speed of 0.046-0.216 m s^{-1} with an average of 0.106 m s^{-1}. In the second transitional period in November, the current moves at moderate speed mainly from southwest to northwest at 0.054-0.343 m s^{-1} with an average of 0.204 m s^{-1}.

At the beginning of the second intermediate season, the current acceleration increases and the direction of the current also shifts towards the western season.

Shoreline change rate*:*2008–2023. Shoreline mapping was performed using the NDWI formula to separate water and land. NDWI values greater than 0 are interpreted as indicative of water areas, whereas values less than or equal to 0 are considered representative of land areas. Based on the results of the shoreline change rate analysis, shoreline changes from 2008 to 2023 were identified. From 2008 to 2011, the coastal areas of Karimunjawa Island and Kemujan Island experienced a decrease in the length of the shoreline by 0.21 km. Within the period 2011-2014, the length of the shoreline decreased by 0.06 km. From 2014 to 2017 the length of the shoreline increased by 0.9 km. Increases in the lengths of the shorelines also occured within the period 2017-2020 and 2020-2023 by 0.61 km and 0.66 km, respectively. The total change in the shoreline length from 2008 to 2023 is 1.9 km. The shoreline analysis using DSAS resulted in a total of 1249 transect lines on Karimunjawa Island and Kemujan Island with a transect distance of 50 m. The rates of erosion and accretion in 2008-2023 are shown in Figure 4.

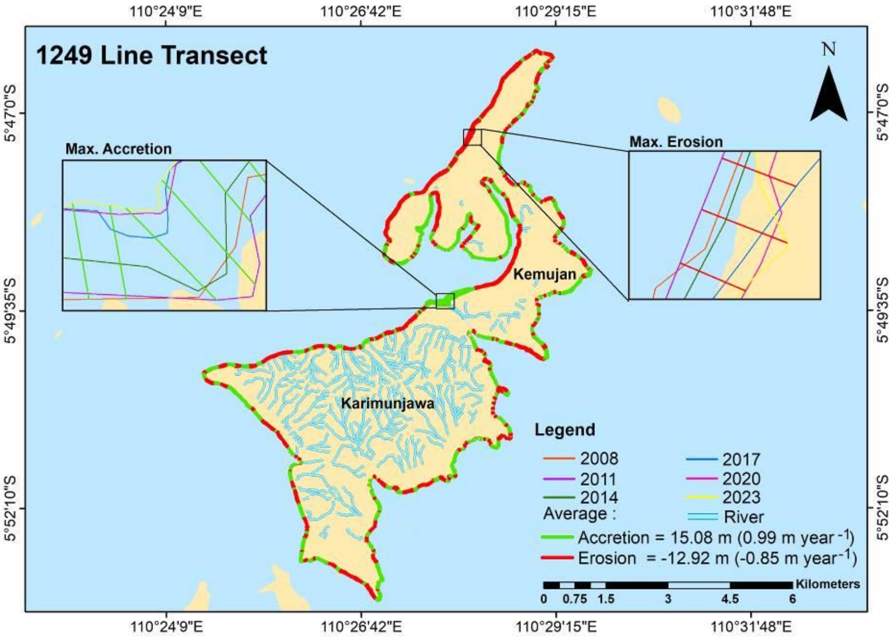

Figure 4. Erosion and accretion rate 2008-2023.

The average erosion rate on Karimunjawa Island and Kemujan Island during 2008-2023 was 15.08 m or 0.99 m $year^{-1}$, while the accretion rate was -12.29 m or -0.85 m $year^{-1}$. The highest rate of erosion was -68.78 m or -4.51 m $year^{-1}$ and the highest accretion rate was 137.22 m or 8.99 m $year^{-1}$. Detailed data of the erosion and accretion rates are shown in Table 1.

Table 1

Erosion and accretion rate values in Karimunjawa Island and Kemujan Island

Island	*Highest*	*Lowest*	*Average*	*Highest*	*Lowest*	*Average*
	NSM erosion (m)			*NSM accretion (m)*		
Karimunjawa	-61.93	-0.01	-11.41	117	0.11	13.30
Kemujan	-68.78	-0.12	-13.74	137.22	8.99	16.40
	EPR erosion (m $year^{-1}$)			*EPR accretion (m $year^{-1}$)*		
Karimunjawa	-4.06	0	-0.75	7.69	0.01	0.87
Kemujan	-4.51	-0.01	-0.90	8.99	0	1.07

For Karimunjawa Island, the NSM data revealed the most severe erosion at -61.93 m and the least at -0.01 m, averaging an erosion rate of -11.41 m. In terms of accretion, the highest NSM recorded was 117 m, the lowest was 0.11 m, with an average accretion rate of 13.30 m. Conversely, on Kemujan Island, the situation presents a nuanced contrast. The maximum erosion NSM was noted at -68.78 m, and the minimal at -0.12 m, both marking an average erosion rate of -13.74 m. However, accretion rates showed a higher peak at 137.22 m and a minimum of 8.99 m, culminating in an average accretion rate of 16.40 m.

Based on the EPR analysis, the most significant erosion rate observed on Karimunjawa Island reached -4.06 m year^{-1}, with the least erosion showing negligible change annually, resulting in an average erosion rate of -0.75 m year^{-1}. Accretion rates on Karimunjawa Island peaked at 7.69 m year^{-1}, with the minimum at 0.01 m year^{-1}, averaging an accretion rate of 0.87 m year^{-1}. On Kemujan Island, the highest erosion rate measured by EPR was -4.51 m year^{-1}, and the lowest was barely measurable at -0.01 m year^{-1}, with an overall average erosion rate of -0.9 m year^{-1}. The highest accretion rate reached 8.99 m year^{-1}, with the lowest showing minimal to no change annually, and an average accretion rate of 1.07 m year^{-1}.

The detailed year-by-year highest and lowest erosion and accretion rates from 2008 to 2023 are presented in Table 2.

Table 2

Erosion and accretion rate values for 2008-2023

Year	*Highest*	*Lowest*	*Average*	*Highest*	*Lowest*	*Average*
	NSM erosion (m)			*NSM accretion (m)*		
2008-2011	-51.11	-0.00	-9.55	54.18	0.00	9.41
2011-2014	-43.48	-0.02	-10.56	52.64	0.00	10.38
2014-2017	-68.05	-0.01	-11.68	109.31	0.02	14.47
2017-2020	-55.07	-0.00	-12.17	51.82	0.00	9.34
2020-2023	-58.61	-0.02	-10.05	64.66	0.00	10.50
2008-2023	-68.78	-0.01	-12.92	137.22	0.02	14.64
	EPR erosion (m year^{-1})			*EPR accretion (m year^{-1})*		
2008-2011	-17.04	-0.00	-3.18	18.06	0.00	3.14
2011-2014	-14.58	-0.01	-3.52	17.55	0.00	3.46
2014-2017	-22.68	-0.00	-3.89	36.44	0.01	4.82
2017-2020	-18.36	-0.00	-4.06	17.27	0.00	3.11
2020-2023	-19.54	-0.01	-3.35	21.55	0.00	3.50
2008-2023	-4.59	-0.00	-0.86	9.15	0.00	0.98

Based on Table 2, NSM and EPR values are shown in 6 observation years from 2008 to 2023. The period between 2008 and 2011 experienced the highest erosion of -51.11 m (-17.04 m year^{-1}) with an average rate of -9.55 m (-3.18 m year^{-1}) and the highest accretion rate of 54.18 (18.6 m year^{-1}) with an average rate of 9.41 m (3.14 m year^{-1}). Meanwhile, for 2011-2014 period, the highest erosion rate reached -43.48 m (-14.58 m year^{-1}) with an average rate of -10.56 m (-3.52 m year^{-1}) and the highest accretion rate of 52.64 (17.55 m year^{-1}) with an average rate of 10.38 m (3.46 m year^{-1}). From 2014 to 2017 it experienced the highest overall erosion and accretion from 2008-2023, the highest erosion value in this period was -68.05 m (-22.68 m year^{-1}) with an average of -11.68 m (-3.89 m year^{-1}) and the highest accretion of 109.31 m (36.44 m year^{-1}) with an average of 14.47 m (4.82 m year^{-1}). During the period 2008-2023 the lowest erosion and accretion occurred at some points, which almost did not change with values ranging from 0 - (-0.2) m (0 - (-0.1) m year^{-1}) and indigo accretion ranging from 0 to 0.2 m (0-0.1 m year^{-1}).

In addition, from 2017 to 2020, the highest erosion was -55.07 m (-18.36 m year^{-1}) with an average of -12.17 m (-4.06 m year^{-1}) and the highest accretion was 51.82 (17.27 m year^{-1}) with an average of 9.34 m (3.11 m year^{-1}). From 2020 to 2023, the highest erosion was -58.61 m (-19.54 m year^{-1}) with an average of -10.05 m (-3.35 m year^{-1}) and the highest accretion was 64.66 (21.55 m year^{-1}) with an average of 10.50 m (3.50 m year^{-1}). The total from 2008 to 2023 experienced the highest erosion of -68.78

m (-4.59 m year^{-1}) with an average of -12.92 m (-0.86 m year^{-1}) and the highest accretion of 137.22 (9.15 m year^{-1}) with an average of 14.64 m (0.98 m year^{-1}).

Shoreline prediction for 2033 and 2043. The future position of the shoreline was predicted using the Kalman filter model on DSAS v5.1. EPR and LRR values obtained from DSAS analysis for 2008-2023 were used to calculate the rate of shoreline change in 2033 and 2043. The Kalman filter method assumes that a thorough linear regression of past shoreline positions is a good estimate of future shoreline positions; however, this assumption may not always be valid. The results of the shoreline prediction are shown in Figure 5.

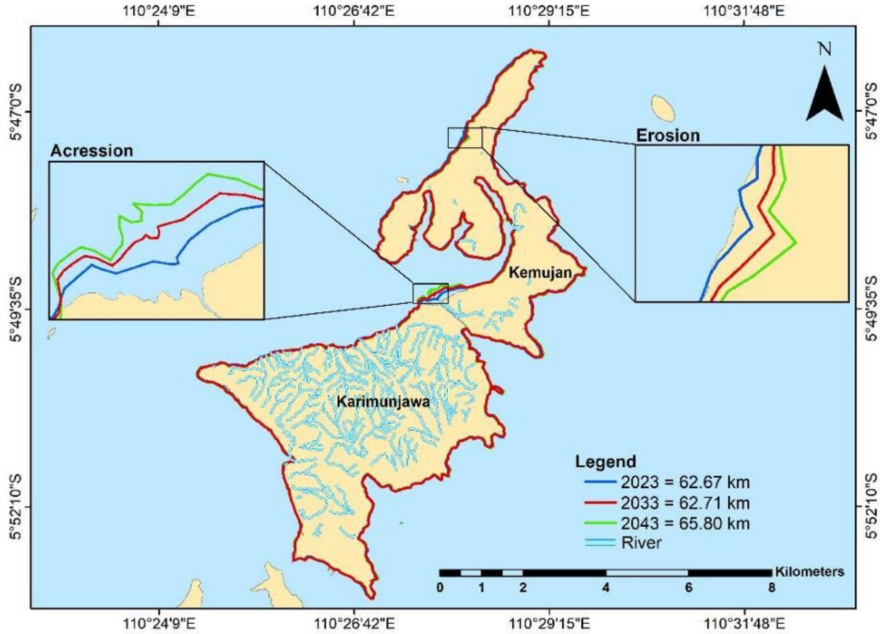

Figure 5. Shoreline change prediction in 2023, 2033 and 2043.

For 2023 to 2043, the coastal areas of Karimunjawa Island and Kemujan Island will increase in the length of the shoreline by 0.04 km and by 3.09 km in 2033-2043. In total, the total increase in the length of the shoreline will be 3.13 km. The EPR values for 10 and 20 years from the periods 2023-2033 and 2034-2043 are shown in Table 3, while the changes in shorelines that occurred on both islands are depicted in Figure 6.

Table 3

Erosion and accretion rate values for 2023-2043

Year	*EPR erosion (m year^{-1})*		*Average*	*EPR accretion (m year^{-1})*		*Average*
	Highest	*Lowest*		*Highest*	*Lowest*	
2023-2033	-6.183	-0.005	-1.125	14.055	0.005	1.276
2033-2043	-6.081	-0.003	-0.921	12.571	0.003	1.105
2023-2043	-6.132	-0.003	-0.979	13.229	0.001	1.174

Between 2023 and 2033, the highest recorded erosion rate was -6.183 m year^{-1}, with an average erosion rate of -1.125 m year^{-1}. The highest accretion rate during this period reached 14.055 m year^{-1}, with an average accretion rate of 1.276 m year^{-1}. From 2033 to 2043, the peak erosion rate slightly decreased to -6.081 m year^{-1}, with an average annual erosion rate of -0.921 m. The highest accretion rate in this decade was 12.571 m year^{-1}, with an average annual accretion rate of 1.105 m. Overall, for the two-decade span from 2023 to 2043, the highest erosion rate averaged out to -6.132 m year^{-1}, with an overall average erosion rate of -0.979 m year^{-1}. The maximum accretion rate observed was 13.229 m year^{-1}, with an overall average accretion rate of 1.174 m year^{-1}.

The lowest total erosion rates recorded at any point during the period from 2023 to 2043 varied between -0.003 and -0.005 m year^{-1}, while accretion rates fluctuated from 0.001 to 0.005 m year^{-1}.

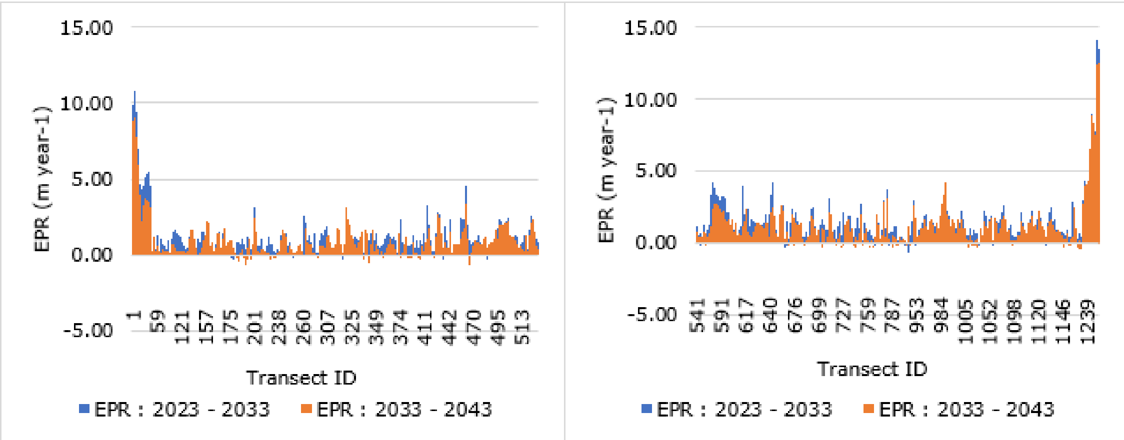

Figure 6. Prediction of shoreline change from 2023 to 2033 and from 2033 to 2043 in Karimunjawa Island and Kemujan Island.

Discussion. The research on the shoreline change along the coasts of Karimunjawa Island and Kemujan Island for the period 2008-2023 was conducted using multitemporal satellite imagery from Landsat 7 and Landsat 8, and SAR imagery from the Sentinel 1 satellite which were analyzed using DSAS. The results show that during the period 2008-2023, there is a change in the length of the shoreline by 1.9 km. From 2008 to 2014, the shoreline in Karimunjawa and Kemujan Islands tended to decrease, and from 2014 to 2023, the shoreline length began to increase. The northwest coast of Kemujan Island is witnessing a prolonged erosion phenomenon, with one of its beaches identified as the site of the most severe erosion, measuring -68.78 m, or an annual rate of -4.51 m as seen in Figure 4. The erosion on both Karimunjawa Island and Kemujan Island is mostly caused by excessive use of land for plantations and ponds. This view is supported by Muskananfola et al (2022a), Li et al (2022), and Mejjad et al (2022) which showed that shoreline change can be caused by natural factors such as oceanographic conditions, topography, sediment types, and vegetation cover such as mangroves, as well as human factors such as land use for settlements, ports, cultivation, plantations, and tourism.

The data indicate that the primary driver of shoreline change on Karimunjawa Island and Kemujan Island is situated in the region that connects the two islands, an area safeguarded by mangroves. This is evidenced by the consistent accretion even though at insignificant rate found in mangrove conservation areas. The highest accretion rate of 137.22 m or 8.99 m year^{-1} is at the border of the two islands separated by rivers. Mangroves can act as a good buffer or sediment trap, inhibiting the sediment transport because the complex root systems make it difficult for seawater to erode or move sediment in areas surrounded by mangroves. Sohel et al (2021) also stated that mangroves can effectively protect shorelines by slowing down and preventing erosion processes.

However, accumulated sediment can have negative impact because it reduces the depth of water bodies, which can trigger a loss of habitat for some types of biota. Hartoko (2010) explains that siltation can cause turbidity in water bodies as turbid water interferes with the vision of fish in the water which eventually reduces the water productivity.

Overall, the shoreline change that occurred on Karimunjawa Island and Kemujan Island in 2008-2023 is not too significant with an average erosion of -12.92 m (-0.86 m year^{-1}) and an average accretion of 14.64 m (0.98 m year^{-1}). Table 2 shows the average value of erosion and accretion on both islands, which tend to be stable. The occurrence of erosion and accretion on Karimunjawa Island and Kemujan Island is related to the transport and deposition of sediments. Sediments from the land are carried to the estuaries by river runoff. The estuary becomes a place of exchange of sediment transport systems from rivers to ocean currents. Sediments transported to the sea can cause erosion, and sediments trapped or deposited in estuaries can cause accretion. This mechanism occurs in the estuaries of mangrove reserves, which are the areas with the highest accretion value. Mangroves have several functions for coastal areas, starting from reducing tidal waves, protecting against coastal erosion, retaining mud and trapping sediment for the surrounding area (Senoaji & Hidayat 2016).

The process of sediment extraction and deposition is also influenced by the presence of sea currents around Karimunjawa Island and Kemujan Island. The results of the analysis of the sea current patterns in Figure 4 show that the current speed around Karimunjawa Island and Kemujan Island is in the moderate category in the transition season II (November) - western season (February) and in the slow category in the transition season I (May) - eastern season (August). In the western season, the current moves from southwest to northeast, and in the eastern season, the current moves from southeast to northwest. Based on the results of the analysis of the ocean current patterns, it is estimated that the highest sediment transport and deposition occurs during the transition season II - western season, which is between September and February. The constantly moving current is able to transport the sediment and influences the shape of the beach (Lubis et al 2020). Different types of sediment transported and deposited on the coast are related to the origin of the sediment source.

The sediments samples collected from 12 ground control points have fine sand, medium sand, coarse sand and boulder texture types. Sediments found on Karimunjawa Island and Kemujan Island are predominantly sand with differences in size at several locations. Areas close to land or mangroves and river mouths have predominantly fine sediment types ranging from fine sand to medium sand, while areas in the form of land protruding into the sea and far from river mouths have predominantly coarser sediment types ranging from coarse sand to boulders. Areas wtih highest erosion rate in the northwestern part of Kemujan Island had medium sand sediment with an average size of 297.1 μm, while the area that experienced the highest accretion in the mangrove reserve near the estuary had medium sand sediment with an average size of 461.6 μm. The northwestern part of Kemujan Island is an open area with high erosion rate. Meanwhile, the mangrove area in Kemujan Island is not adjacent to the open sea as it is slightly covered by land protruding, thereby the current in the area is slower and sediments tend to get trapped and settle. Kuang et al (2022) stated that the size of the current can produce energy that is able to transport sediment from one place to another.

The results of erosion and accretion analysis that have been obtained were then analyzed to obtain prediction values for shoreline changes using NSM and EPR values in the next 10 and 20 years, 2033 and 2043. The prediction results show that in the next 10 years from 2023 to 2033, the shoreline length of Karimunjawa Island and Kemujan Island will increase by 0.04 km and by 3.09 km within the next 10 years from 2033 to 2043. In total, the shoreline length will increase by 3.13 km in the next 20 years from 2023 to 2043. The average erosion that occurs during 2023-2043 is 0.979 m year^{-1}, while the average accretion that occurs is 1.174 m year^{-1}. Based on Table 3 in the period every 10 years from 2023, 2033 and 2043, Karimunjawa Island and Kemujan Island did not experience significant erosion and accretion. Referring to the shoreline prediction chart presented in Figure 6, the patterns of erosion and accretion expected in 2033 and 2043 for Karimunjawa Island and Kemujan Island appear to stabilize. The highest rates of erosion observed during the two periods from 2023 to 2033 and 2033 to 2043 show no significant variation, with erosion rates recorded at -6.183 m year^{-1} and -6.081 m year^{-1}, respectively, both located on the northwest coast of Kemujan Island. Similarly, the highest accretion values that occurred from 2023 to 2033 and from 2033 to 2043 also did not experience significant differences, the erosion values that occurred were 14.055 m year^{-1} and 12.571 m year^{-1} located in mangrove conservation areas and river estuaries. This is consistent with research by Muhammad & Mardiatno (2023), who found that shoreline changes on Karimunjawa and Kemujan Islands tended to be stable.

Based on the results of the research, the shoreline changes on Karimunjawa Island and Kemujan Island tend to be stable. However, it is still important to regularly monitor the erosion and accretion in the area. Policy and regulation should be created by the Karimunjawa National Park Agency regarding erosion and accretion. While the majority of residents do not actively consider the impacts of erosion and accretion, a subset of the community is consciously engaging in efforts to mitigate erosion. For instance, in the northwestern area of Kemujan Island, the community has independently constructed a groin to inhibit the sediment transport and as boat mooring.

Conclusions. It can be taken into conclusion that the shoreline change which occurred in 2008-2023 was rather stable, with an average erosion of -12.92 m (-0.86 m year^{-1}) and an average accretion of 14.64 m (0.98 m year^{-1}). The currents around the island are also dominated by slow-moderate currents which do not significantly contribute to the sediment transportation and deposition which are dominated by sand. The shoreline change prediction for the next 10 years (2033) and 20 years (2043) is expected to be stable.

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Conflict of interest. The authors declare that there is no conflict of interest.

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Authors:
Alfa Bagas Putra Trinida, Aquatic Resources Management Master Program, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia, e-mail: alfabagas214@gmail.com; alfabagasputra14@students.undip.ac.id
Max Rudolf Muskananfola, Department of Aquatic Resources, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia, e-mail: maxmuskananfola@yahoo.com
Suryanti Suryanti, Department of Aquatic Resources, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia, e-mail: suryantidr@gmail.com

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