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Research Article

Analysis of shoreline changes along the coastal area of Biak Island (Biak Numfor Regency, Indonesia) using multitemporal Landsat images

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Abstract

Monitoring shoreline changes is important in detecting abrasion and accretion in coastal areas. This study aimed to determine the level of shoreline change caused by abrasion and accretion and estimate the change rate. The study area covers coastal areas in ten Districts in Biak Numfor Regency (only on Biak Island). Six Landsat image datasets (1997, 2002, 2007, 2013, 2018, and 2022) were used to determine the coastline. Shoreline changes were analyzed using DSAS software. The results of digitizing the shoreline show a change in the length of the shoreline during the six data periods. Based on NSM and EPR for the last ten years (2013-2022), the average shoreline changes due to abrasion range from -6.65 to -13.16 m with an abrasion rate of -0.76 to -1.50 m/year. Meanwhile, the average shoreline changes due to accretion ranged from 4.64 to 8.45 m with an accretion rate of 0.53 m/year to 0.96 m/year. Changes in shoreline based on the rate of abrasion and accretion vary greatly in each district along the coastal area of Biak Numfor Regency, depending on the EPR value of each transect. Spatially, high abrasion and very high abrasion are widely distributed in Oridek, Biak Utara, Swandiwe, and Warsa Districts. Medium and high accretion were found in Yawosi, Bindifuar, and Oridek Districts. Because there has been a change in the coastline due to abrasion, planning efforts to mitigate coastal areas are very necessary.

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Introduction

The coastal area is an area that is very vulnerable to various natural phenomena and anthropogenic activities (Kaly et al., 2004). One of the important aspects of assessing vulnerability in coastal areas is shoreline change (Pendleton et al., 2010). The coastline is defined as the boundary between the land surface and sea level, where the boundary can vary in shape and change dynamically (Cui and Li, 2011; Mujabar and Chandrasekar, 2013; Nath et al., 2021). Coastline change is a dynamic process and continues through various factors, such as land erosion (abrasion) and land addition (accretion). The shoreline features depend on the interaction between waves, tides, rivers, storms, tectonic processes, and physical processes that occur dynamically in the coastal area (Passeri et al., 2015).

Monitoring shoreline changes is important for detecting abrasion and accretion in coastal areas and coastal morphodynamic studies (Armenio et al., 2019; Baig et al., 2020). In addition, coastal abrasion is a tentative hazard for communities in coastal areas because they are very vulnerable to increased disasters (Baig et al., 2020). Various methods have been developed to monitor and map changes that occur in coastal areas, including shoreline changes. One of the most popular methods is the use of satellite remote sensing technology. Remote sensing data has been widely used to study shoreline changes because of its wide coverage, high resolution, multi-spectral, multi-temporal capabilities, and is cheaper than conventional techniques (Cendrero, 1989). Landsat satellite imagery is the most widely used for studying dynamics of shoreline change worldwide because the data can be accessed free of charge.

Shoreline changes are easier to detect and analyse using geospatial techniques that combine satellite remote sensing and Geography Information System (GIS) in spatial models (Nassar et al., 2019; Yulianto et al., 2019; Koulibaly and Ayoade, 2021) or using the Digital Shoreline Analysis System (DSAS) (Thieler et al., 2009). Currently, DSAS software is very popularly used to automatically detect and calculate shoreline changes (Kankara et al., 2015; Nhan et al., 2018; Elnabwy et al., 2020; Nath et al., 2021; Koulibaly and Ayoade, 2021). DSAS software can provide a better understanding of the dynamics and trends of shoreline change, where shoreline data extracted from multi-temporal satellite imagery is analysed to measure the rate of abrasion and accretion that occurs along with coastal areas (Ryabchuk et al., 2012; Yulianto et al., 2019; Dey et al., 2021; Zonkouan et al., 2022). Calculating the shoreline change rate is also very effective by including identified attribute positions at different times (Cohen and Lara, 2003; Yulianto et al., 2019; Dey et al., 2021).

Currently, spatial data and information related to shoreline changes in Biak Numfor Regency are unavailable. Therefore, the current study is an important step in understanding the dynamics of shoreline change occurring in the coastal area of Biak Numfor Regency and is the first step to reducing the risk of coastal abrasion. In addition, the coastal area of Biak Numfor Regency, which is geographically located and directly opposite the high seas (Pacific Ocean), is therefore considered to have the potential to cause disasters in coastal areas.

This study aimed to analyze and map shoreline changes due to abrasion and accretion, as well as the rate of shoreline change in the coastal area of Biak Numfor Regency.

Materials and Methods

Description of the study area

Biak Numfor Regency is one of the regencies in Papua Province, which is geographically located at 0°21'-1°31' latitude, 134°47'-136°48' longitude, with an area of 15,124 km^2 (land and sea area are 2,602 km^2 and 12,522 km^2, respectively) (Badan Pusat Statistik Kabupaten Biak Numfor, 2021). Biak Numfor Regency consists of 2 (two) small islands, namely Biak and Numfor Islands, as well as more than 42 very small islands (including the Padaido archipelago). Biak Numfor Regency is a group of islands located in the north of the island of Papua and is directly opposite the Pacific Ocean. Administratively, Biak Numfor Regency consists of nineteen districts. Still, only ten districts on Biak Island have coastal areas that are the study area in this study (except Samofa and Andey Districts) (Figure 1). The coastal area of Biak Numfor Regency is rich in coastal natural resources, such as mangrove ecosystems (Tablaseray et al., 2018), seagrass ecosystems (Dewi et al., 2017), coral reef ecosystems, and reef fish (Rumkorem et al., 2019), and the development of coastal and marine tourism potential (Rumpaidus et al., 2019).

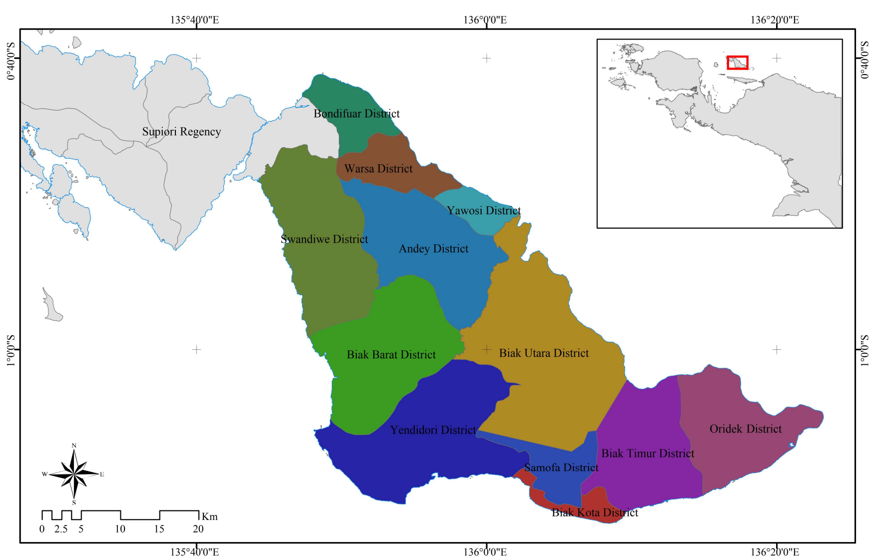

Figure 1. Map of the study area on Biak Island (Biak Numfor Regency, Indonesia).

Landsat images used

Multi-temporal Landsat images from 1997 to 2022 were used to track and identify shoreline changes in the coastal area of Biak Numfor Regency downloaded from the website http://earthexplorer.usgs.go (Path/Row: 104/61). In this study, determining the coastline requires several satellite images to determine the coastline in the same period (Table 1). For this reason, it is assumed that there is no difference in the position of the coastline between the main image and the supporting image. The main and supporting images are used because the large study area and Landsat imagery free from cloud cover are unavailable. In addition, there was also damage to the Scan Line Corrector (SLC-Off) of the Landsat 7 ETM+ satellite (for the 2007 coastline), so the resulting image data was not perfect (there was stripping in the satellite imagery data).

Data processing and analysis

The stages for processing and analyzing Landsat satellite image data to determine shoreline changes along the coastal area of Biak Numfor Regency are shown in Figure 2.

Images correction

Geometric correction in Landsat images is a step to correct geometric recording errors so that the resulting image corresponds to the actual position on the earth. Geometric correction is done by using a map of the earth that has been geometrically corrected. The coordinate system used is WGS 1984 UTM Zone 53S.

Table 1. Landsat image dataset used to determine the shoreline in Biak Numfor Regency, Indonesia.

Year	Satellite/Sensor	Acquisition date
1997	Landsat 5 TM	1997/03/24[a]
		1996/11/16[b]
2002	Landsat 7 ETM+	2002/05/17
2007	Landsat 7 ETM+	2007/05/15[a]
		2007/09/20[b]
2013	Landsat 8 OLI	2013/12/01[a]
		2013/10/14[b]
		2013/04/21[b]
2018	Landsat 8 OLI	2018/07/08[a]
		2018/10/28[b]
2022	Landsat 9 OLI-2	2022/04/06

Note: [a] main image; [b] supporting image.

Radiometric and atmospheric correction is an image recovery process to improve image quality due to interference from the atmosphere using ENVI 5.1 software. In this study, the radiometric correction process was carried out using Radiometric Calibration to sharpen the image display, while the atmospheric correction used the FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) module to eliminate atmospheric disturbances (water vapor and aerosols).

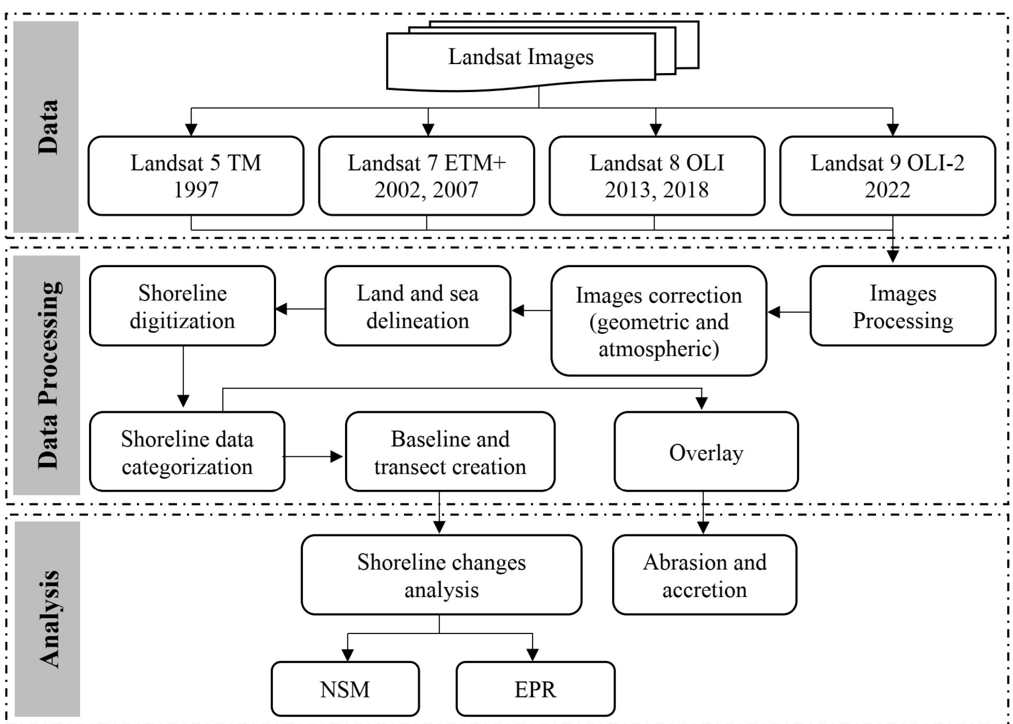

Figure 2. Flowchart of extraction, processing, and analysis of Landsat satellite images for shoreline changes.

Delineation and digitizing

Land and sea delineation aims to provide a clear picture of the boundary between land and sea so that the resulting coastline position is accurate. The Modified Normalized Difference Water Index (MNDWI) was used for land and sea delineation. For Landsat 5 TM and Landsat 7 ETM+ images using the following Equation 1 (Xu, 2006). Meanwhile, Landsat 8 OLI and Landsat 9 OLI-2 images use the following Equation 2 (Ko et al., 2015).

$$\text{MNDWI} = \frac{(\text{Green} - \text{MIR})}{(\text{Green} + \text{MIR})}$$

$$\text{MNDWI} = \frac{(\text{Green} - \text{SWIR 1})}{(\text{Green} + \text{SWIR 1})}$$

where, MIR is the mid-infrared band on Landsat 5 TM and Landsat 7 ETM+, and SWIR is the short wavelength infrared band on Landsat 8 OLI and Landsat 9 OLI-2.

The image resulting from the MNDWI process was then digitized to produce coastline data for 1997, 2002, 2007, 2013, 2018, and 2022. The coastline (polyline features) was digitized using ArcMap 10.8.1 software.

Baselines and transects

Three input parameters are required for shoreline change analysis using Digital Shoreline Analysis System (DSAS) software: shorelines, baseline, and transects. In this study, the baseline by buffering the 2018 shoreline was as far as 100 m inland. The transects were made toward the sea, with the transect length being 200 m from the baseline and the interval between transects being 100 m.

Analysis of shoreline changes

Shoreline changes were analyzed using Net Shoreline Movement (NSM) statistical approach and End Point Rate (EPR) in DSAS software. NSM was used to measure the distance of shoreline change between the oldest and youngest shorelines in each transect. The shoreline changes were then analyzed to obtain the rate of shoreline change using the EPR technique. The main advantages of EPR are the ease of calculating the rate of shoreline change and the minimum requirement of only two shoreline datasets (Thieler et al., 2009). The NSM and EPR calculated in this study were the last ten years, which were determined following the following equations (Thieler et al., 2009):

NSM [m] = Distance between A and B shorelines

$$\text{EPR [m/year]} = \frac{\text{NSM}}{\text{Time between A and B shorelines}}$$

where, A and B shorelines are the oldest (2013) and youngest (2022) shorelines, respectively. The rate of shoreline change based on the EPR value can indicate the level of vulnerability of the coastline which is grouped into five categories, namely EPR<-2 (Very high abrasion; Very vulnerable), -2<EPR<-1 (High abrasion; Vulnerable), -1<EPR<1 (Stable; Moderate), 1<EPR<2 (Medium accretion; Not susceptible), and EPR>2 (High accretion; Very not susceptible) (Thieler and Hammar-Klose, 1999).

Results

Shoreline length

One of the consequences of shoreline dynamics is the change in shoreline length from time to time. The results of interpretation of satellite images and digitization of coastlines from six multi-temporal Landsat satellite imagery datasets (1997, 2002, 2007, 2013, 2018, and 2022) show that there is a change in the position of the coastline on almost all coasts in the study area (Figure 3). This result causes changes in the length of the coastline of each district in Biak Numfor Regency which varies (Table 2). However, the change in the length of the coastline is not significant. Overall, the 2002 coastline is the longest for the entire study area compared to 1997, 2007, 2013, 2018, and 2022 coastlines at 244.33, 241.48, 244.31, 241.91, 241.97, and 242.76 km, respectively.

Table 2. Changes in the length of the shoreline of Biak Numfor Regency, Indonesia.

Districts	**Shoreline length (km)**					
	1997	**2002**	**2007**	**2013**	**2018**	**2022**
Swandiweri	27.00	27.25	27.17	27.11	26.64	27.04
Biak Barat	14.95	15.20	15.11	14.93	14.91	15.01
Yendidori	40.69	41.01	41.06	40.30	40.59	40.71
Biak Kota	19.03	19.20	19.24	19.02	19.21	19.11
Biak Timur	20.01	20.10	20.09	20.06	20.20	20.03
Oridek	47.68	47.86	47.83	47.55	47.61	47.72
Biak Utara	35.01	35.20	35.20	35.02	35.11	35.03
Yawosi	8.32	8.42	8.43	8.29	8.21	8.27
Warsa	12.05	12.13	12.19	12.00	11.93	12.07
Bondifuar	17.74	17.97	17.99	17.64	17.56	17.77
Total	242.48	244.33	244.31	241.91	241.97	242.76

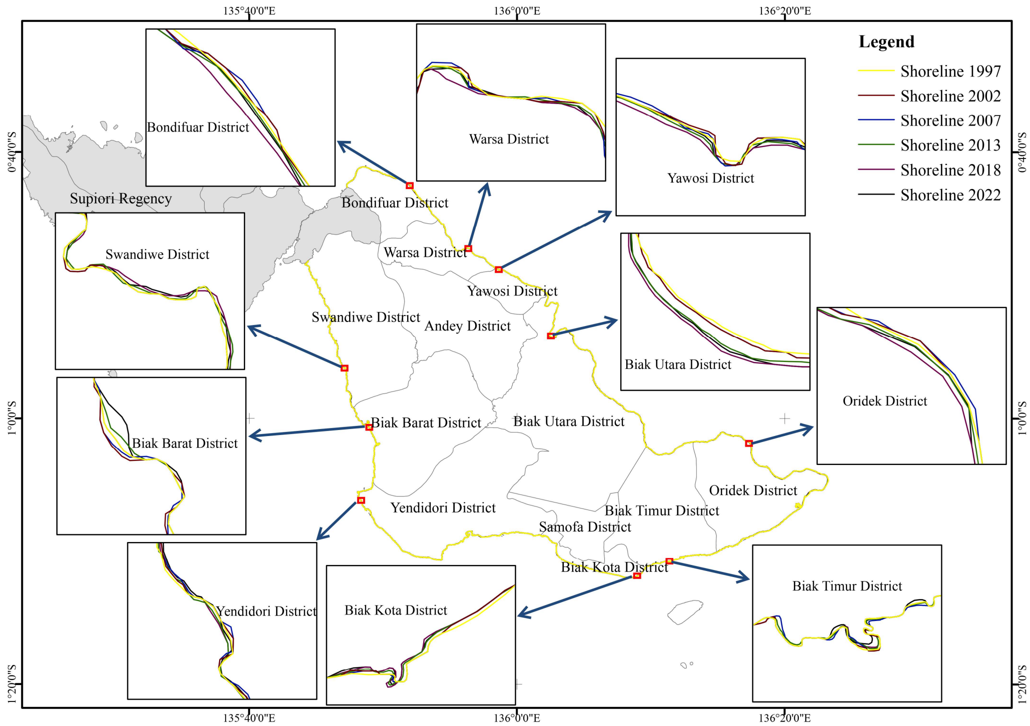

Figure 3. Map of changes in the shoreline of Biak Numfor Regency from 1997 to 2022.

Abrasion and accretion

The area of abrasion and accretion in each district from the overlay results is presented in Table 3. Generally, the coastal area of Biak Numfor Regency is very dynamic, with an increase in the beach area due to accretion. At the same time, there is a decrease in the beach area due to abrasion. The highest abrasion occurred between 2007 and 2013, with an area of about 140.59 ha of abrasion. The area is almost three times wider than the abrasion in the previous period (between 2002 and 2007). Likewise, the higher accretion area between 2007 and 2013 was 66.61 ha.

Table 3. Estimated area of abrasion and accretion in Biak Numfor Regency, Indonesia.

Districts		**1997-2002**	**2002-2007**	**2007-2013**	**2013-2018**	**2018-2022**
Swandiwe	Abrasion (ha)	6.93	7.71	17.06	8.65	19.59
	Accretion (ha)	3.01	3.45	9.82	11.70	4.52
Biak Barat	Abrasion (ha)	2.75	5.24	5.07	2.01	8.18
	Accretion (ha)	3.29	1.03	6.52	6.75	1.29
Yendidori	Abrasion (ha)	9.55	10.82	10.44	5.92	9.95
	Accretion (ha)	3.88	6.20	13.36	7.23	7.86
Biak Kota	Abrasion (ha)	3.90	2.94	5.47	2.03	4.15
	Accretion (ha)	4.30	2.69	3.55	2.02	1.46
Biak Timur	Abrasion (ha)	11.62	4.31	13.18	12.50	6.95
	Accretion (ha)	6.41	3.90	7.62	3.85	7.85
Oridek	Abrasion (ha)	16.81	9.15	50.80	25.40	12.46
	Accretion (ha)	13.92	5.32	5.36	4.64	13.01
Biak Utara	Abrasion (ha)	18.61	1.80	17.47	14.45	8.86
	Accretion (ha)	5.23	1.15	6.53	4.64	8.68
Yawosi	Abrasion (ha)	2.78	2.09	4.09	3.79	1.60
	Accretion (ha)	1.43	1.35	1.73	1.19	5.55
Warsa	Abrasion (ha)	6.60	2.16	5.97	5.13	6.02
	Accretion (ha)	0.66	1.57	4.29	1.67	3.17
Bondifuar	Abrasion (ha)	10.09	4.40	11.05	8.50	5.55
	Accretion (ha)	2.07	2.10	7.82	3.58	10.95

Net Shoreline Movement (NSM) and End Point Rate (EPR)

A total of 2356 transects were used to analyze shoreline changes along the coastal area of Biak Numfor Regency using DSAS software. Abrasion and accretion were detected in 1180 and 684 transects, respectively. More abrasion occurred in Oridek and Biak Utara Districts than in the other districts, with 258 and 211 transects, respectively. While accretion mostly occurred in Yendidori and Oridek Districts, as many as 153 and 100 transects, respectively. However, based on the percentage of detected abrasion and accretion to the number of transects in each district, the percentage of abrasion occurring was higher in the Swandiwe and Warsa Districts (63% of the total 164 transects and 76 transects, respectively), while accretion in Yawosi District was 54% of the 83 transects.

Based on the results of the NSM analysis for the period 2013 to 2022, the highest shoreline shift distances due to abrasion occurred in the Oridek, Biak Barat, and Biak Utara Districts as -83.65, -65.58, and -44.69 m, respectively. Meanwhile, the highest coastline shift due to accretion occurred in Swandiwe, Yendidori, and Bondifuar Districts as far as 72.33, 68.83, and 55.33 m, respectively. However, the average distance of shoreline shift due to abrasion is highest in Biak Barat District, while due to accretion in Yawosi District (Table 4). The mean shoreline changes due to abrasion and accretion in the study area ranged from -6.65 to -13.16 m and 4.64 to 8.45 m, respectively. Table 4 also presents the shoreline change rate due to abrasion and accretion (EPR value) for 2013 to 2022. The average shoreline change rate in Biak Numfor Regency ranges from -0.80 to 0.24 m/year. In particular, the rate of shoreline changes due to abrasion and accretion ranged from -0.76 to -1.50 m/year and 0.53 to 0.96 m/year, respectively.

Based on EPR data for each transect, high abrasion rates occurred in Oridek, Biak Barat, and Biak Utara Districts, namely -9.55, -7.49, and -5.10 m/year, respectively. Meanwhile, high accretion rates occurred in Swandiwe, Yendidori, and Bondifuar Districts of 8.25, 7.86, and 6.31 m/year, respectively. Based on the average rate of NSM and EPR (Table 4), abrasion is more dominant and quite significant than accretion in seven districts. Only in Yawosi and Bondifuar Districts where accretion is dominant because the movement of the coastline and the rate of shoreline change due to accretion is higher than that of abrasion.

Table 4. NSM and EPR along the shoreline of Biak Numfor Regency from 2013 to 2022.

Districts	Net Shoreline Movement (m)			End Point Rates (m/year)		
	Abrasion	Accretion	Average rate	Abrasion	Accretion	Average rate
Swandiwe	-10.43	7.91	-5.46	-1.19	0.90	-0.62
Biak Barat	-13.16	8.12	-3.61	-1.50	0.93	-0.41
Yendidori	-7.11	6.58	-0.67	-0.81	0.75	-0.08
Biak Kota	-6.65	5.41	-2.66	-0.76	0.62	-0.30
Biak Timur	-8.35	6.44	-3.01	-0.92	0.85	-0.32
Oridek	-10.42	6.85	-5.59	-1.19	0.78	-0.64
Biak Utara	-12.67	6.88	-4.92	-1.18	0.77	-0.59
Yawosi	-7.29	8.45	2.41	-0.83	0.96	0.28
Warsa	-9.92	4.64	-7.01	-1.13	0.53	-0.80
Bondifuar	-7.55	8.08	0.32	-0.86	0.92	0.04

The shoreline change rate in each transect can show the spatial distribution of shoreline vulnerability due to abrasion and accretion (Figure 4). The level of abrasion and accretion varies greatly in each district along the coastal area of Biak Numfor Regency. The coastline in the southern part of the Biak Timur District is dominant in the stable category (-1<EPR<1), and only a small part near the border with the Biak Kota District is in the high abrasion category (-2<EPR<-1) (Figure 4a). On the other hand, the distribution of coastline vulnerability in the northern part of the Biak Timur District is more varied (categories of high abrasion, stable, and moderate accretion). Likewise, the coastline in Oridek District, in the southern part, is dominated by the stable category, and some areas have high to very high abrasion categories (EPR<-2) (Figure 4a). Meanwhile, the high abrasion category is dominant and is more widely spread in the northern part of the Oridek District. In Biak Utara District, the high abrasion category to the very high abrasion category was found more and spread along the coastline (except near the border with Yawosi District; stable category dominant) (Figure 4b). Coastlines in the stable category are mostly found in Yawosi and Bondifuar Districts (Figure 4c). In fact, the accretion rate is more dominant than the abrasion in the two districts. However, the category of high abrasion is mostly found in Warsa District, which is between Yawosi and Bondifuar Districts. Abrasion is also found in Swandiwe District, which is in the northern part is a high abrasion category and in the southern part (border with Biak Barat District) is a very high abrasion category (Figure 4d). The stable category is dominant along the coastline of Yendidori District to Biak Kota District (Figure 4e). However, in some areas, there are very high abrasion categories, high abrasion, moderate accretion (1<EPR<2), and high accretion (EPR>2) with a small spatial area.

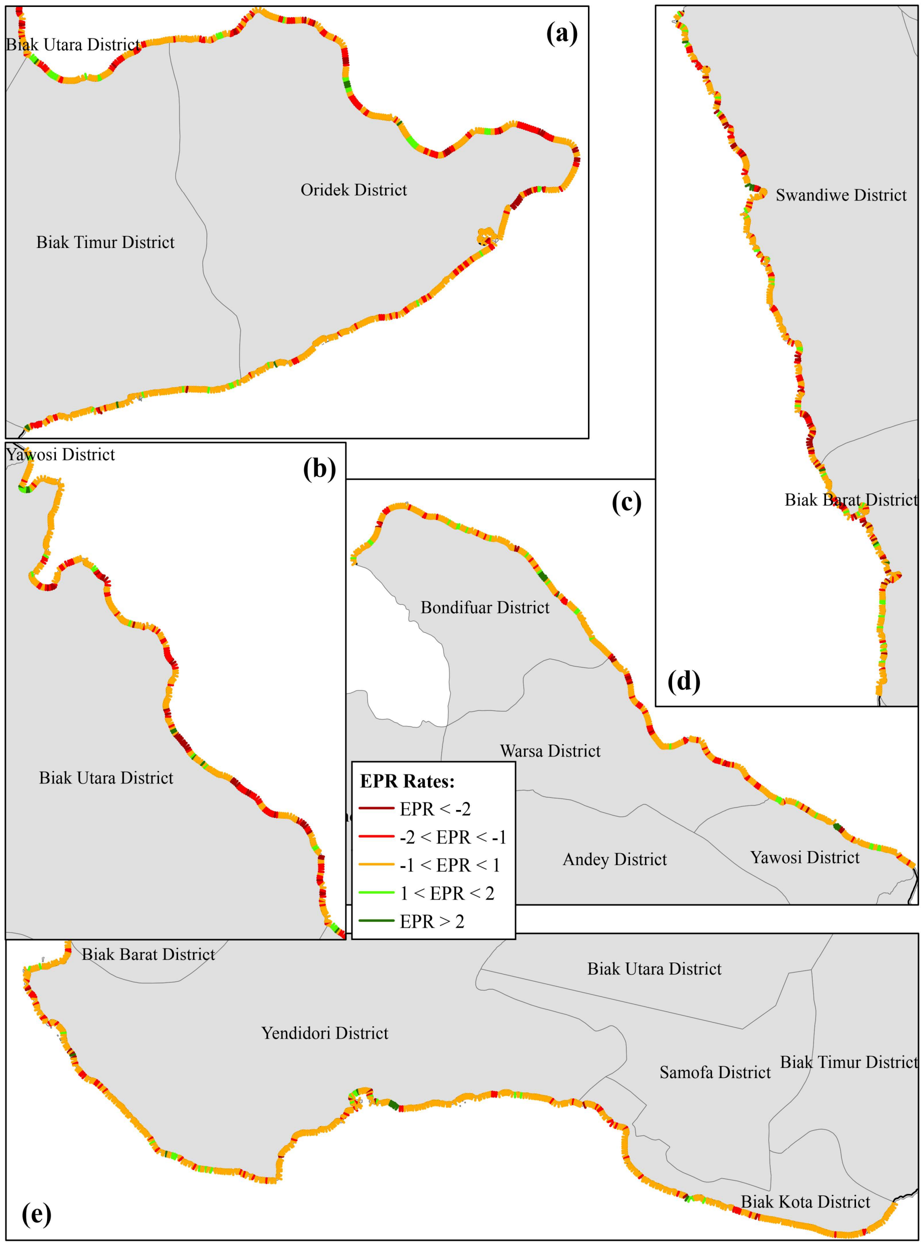

Figure 4. Spatial map of EPR rates from 2013 to 2022: (a) Biak Timur and Oridek Districts; (b) Biak Utara District; (c) Bondifuar, Warsa, and Yawosi Districts; (d) Swandiwe and Biak Barat Districts; (e) Yendidori and Biak Kota Districts.

Discussion

Changes in the coastline are one of the phenomena and a problem often encountered in coastal areas. In this study, the level of shoreline change was analyzed to show the tendency of abrasion and accretion along the coastal area of the Biak Numfor Regency. During the study period, most of the coastal areas of Biak Numfor Regency experienced abrasion, although some coasts experienced accretion. Different coastal landscapes will have varying responses to abrasion or accretion (Koroglu et al., 2019). Abrasion causes the coastline to move towards the land, while accretion causes the coastline to move toward the sea. In general, the coastline movement towards land and sea causes the length of the coastline to increase. However, if there is an abrasion in the area where accretion occurred in the previous period, it will cause the length of the coastline to decrease. Vice versa, if accretion occurs in areas where abrasion occurred in the previous period, the length of the coastline will also decrease. Changes in coastlines can affect the vulnerability of the coastal environment (Yulianto et al., 2019), so it becomes one of the important parameters in determining the level of vulnerability of coastal areas (Pendleton et al., 2010). In the context of coastal vulnerability, shoreline change is used as an indicator of potential impacts of climate change and can be considered coastal resilience capacity (Koroglu et al., 2019).

In this study, the shoreline change rate due to abrasion ranges from -0.76 to -1.50 m/year, while accretion ranges from 0.53 to 0.96 m/year. This rate of change is lower than in some coastal areas in Indonesia. The results of Nugraha et al. (2017) showed a fairly high shoreline change rate due to abrasion and accretion in Gianyar Regency, ranging from -1.32 to -3.73 m/year and 0.51 to 8.61 m/year, respectively. Likewise, Klungkung Regency shows a fairly high rate of shoreline change due to abrasion and accretion, ranging from -0.88 to -8.87 m/year and 0.63 to 2.68 m/year, respectively. The research results by Aryastana et al. (2017) show that the average shoreline change rate due to abrasion in Denpasar City and Badung Regency is -1.07 and -1.96 m/year, respectively. Setyawan et al. (2021) found a higher shoreline change rate in the coastal area of the Kuala Pesisir District (Nagan Raya Regency, Aceh) at -5.85 m/year (due to abrasion) and 6.38 m/year (due to accretion).

Coastline change is a dynamic process in coastal areas that can occur in the short or long term (Mutaqin, 2017). In general, shoreline changes occur slowly but can occur in a short time if supported by natural factors and human activities (Kaly et al., 2004). Changes in coastline due to abrasion and accretion in coastal areas are not only determined by a single factor but by several factors and their interactions (Passeri et al., 2015). Natural factors can come from the influence of hydrodynamic processes that occur in the sea, such as wave crashes, changes in current patterns, and tidal variations (Mutaqin, 2017), as well as tectonic activity that causes large waves (Mutaqin, 2017; Hamuna et al., 2019). Sea level rise due to climate change can also impact shoreline changes (Marfai et al., 2007; Marfai, 2014). Human activities impacting shoreline changes are diverse, and the implications will be broad due to increased activity and development in coastal areas. The causes of shoreline change due to human activities include the conversion of coastal land for development (Zonkouan et al., 2022), sand mining which can trigger changes in current and wave patterns (Shuhendry, 2004), and the felling of coastal vegetation, especially mangrove trees (Shuhendry, 2004; Angkotasan et al., 2012). Increased development and human activities along coastal areas can cause coastal and marine environments to be more vulnerable and eliminate their potential (Zonkouan et al., 2022).

The causes of natural shoreline changes are certainly unavoidable because the marine environment has its cycle but can be anticipated by developing appropriate adaptive strategies. One of them is making breakwaters in coastal areas. Breakwaters can significantly reduce abrasion rates (Lubis, 2011; Saad et al., 2021). In the study area, the breakwater that stretches almost along the coastal area of Mokmer and Parai Villages in Biak Kota District and Orwer, Woniki, and Inof villages in East Biak District has an impact on the low level of abrasion, so the stable category spatially dominates. Another barrier to abrasion is mangrove vegetation because it has a dense root system that can withstand the release of sediment particles so that coastal abrasion can be prevented (Hartati et al., 2016). If mangroves are cut down, large currents or waves will directly lead to the beach, which can cause abrasion.

Conclusion

The availability of multi-temporal Landsat satellite imagery and DSAS software are very helpful in detecting and monitoring shoreline changes. This study's results clearly show a change in the coastline along the coastal area of Biak Numfor Regency, both due to abrasion and accretion. In the last ten years, the average shoreline changes due to abrasion ranged from -6.65 to -13.16 m, with an abrasion rate of -0.76 to -1.50 m/year. Meanwhile, the average shoreline changes due to accretion ranged from 4.64 to 8.45 m with an accretion rate of 0.53 m/year to 0.96 m/year. Because there has been a change in coastline due to high accretion in some parts of the coastal area, planning and follow-up efforts for coastal mitigation are needed. In addition, efforts to increase public awareness and participation are also needed in protecting the coastal environment.

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References

Angkotasan, A.M., Nurjaya, I.W. and Natih, N.M. 2012. Shoreline change analysis of the south west coast at Ternate Island, North Molucas Province. *Jurnal Teknologi Perikanan dan Kelautan* 3(2):11-22, doi:10.24319/jtpk.3.11-22 (*in Indonesian*).

Armenio, E., Serio, F.D., Mossa, M. and Petrillo, A.F. 2019. Coastline evolution based on statistical analysis and modeling. *Natural Hazards and Earth System Sciences* 19(9):1937-1953, doi:10.5194/nhess-19-1937-2019.

Aryastana, P., Ardantha, I.M. and Agustini, N.K.A. 2017. Analysis of coastal line changes and erosion rate in Denpasar City and Badung Regency with spot satellite image. *Jurnal Fondasi* 6(2):100-111, doi:10.36055/jft.v6i2.2634 (*in Indonesian*).

Baig, M.R.I., Ahmad, I.A., Shahfahad, Tayyab, M. and Rahman, A. 2020. Analysis of shoreline changes in Vishakhapatnam coastal tract of Andhra Pradesh, India: an application of digital shoreline analysis system (DSAS). *Annals of GIS* 26(4):361-376, doi:10.1080/19475683.2020.1815839.

BPS (Badan Pusat Statistik) Kabupaten Biak Numfor. 2021. Biak Numfor Regency in Figures 2021. Badan Pusat Statistik Kabupaten Biak Numfor, Biak Numfor (*in Indonesian*).

Cendrero, A. 1989. Mapping and evaluation of coastal areas for planning. *Ocean and Shoreline Management* 12(5-6):427-462, doi:10.1016/0951-8312(89)90023-4.

Cohen, M.C.L. and Lara, R.J. 2003. Temporal changes of mangrove vegetation boundaries in Amazonia: Application of GIS and remote sensing techniques. *Wetland Ecology Management* 11:223-231, doi:10.1023/A:1025007331075.

Cui, B.-L. and Li, X.-Y. 2011. Coastline change of the Yellow River estuary and its response to the sediment and runoff (1976-2005). *Geomorphology* 127(1-2):32-40, doi:10.1016/j.geomorph.2010.12.001.

Dewi, C.S.U., Subhan, B. and Arafat, D. 2017. The diversity, density, and covering area of seagrass in Biak Island waters, Papua. *Depik: Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan* 6(2):122-127, doi:10.13170/depik.6.2.6227 (*in Indonesian*).

Dey, M., Priyaa, S. and Jena, B.K. 2021. A shoreline change detection (2012-2021) and forecasting using digital shoreline analysis system (DSAS) tool: a case study of Dahej Coast, Gulf of Khambhat, Gujarat, India. *Indonesian Journal of Geography* 53(2):295-309, doi:10.22146/ijg.56297.

Elnabwy, M.T., Elbeltagi, E., El Banna, M.M., Elshikh, M.M.Y., Motawa, I. and Kaloop, M.R. 2020. An approach based on Landsat images for shoreline monitoring to support integrated coastal management: a case study, Ezbet Elborg, Nile Delta, Egypt. *ISPRS International Journal of Geo-Information* 9:199, doi:10.3390/ijgi9040199.

Hamuna, B., Kalor, J.D. and Tablaseray, V.E. 2019. The Impact of tsunami on mangrove spatial change in eastern coastal of Biak Island, Indonesia. *Journal of Ecological Engineering* 20(3):1-6, doi:10.12911/22998993/95094.

Hartati, R., Pribadi, R., Astuti, R.W., Yesiana, R. and Yuni, H.I. 2016. A study of coastal security and protection in the coastal area of Tugu and Genuk Districts, Semarang City. *Jurnal Kelautan Tropis* 19(2):95-100, doi:10.14710/jkt.v19i2.823 (*in Indonesian*).

Kaly, U., Pratt, C. and Mitchell, J. 2004. The Environmental Vulnerability Index (EVI) 2004. SOPAC Technical Report 384.

Kankara, R.S., Selvan, S.C., Markose, V.J., Rajan, B. and Arockiaraj, S. 2015. Estimation of long and short term shoreline changes along Andhra Pradesh coast using remote sensing and GIS techniques. *Procedia Engineering* 116:855-862, doi:10.1016/j.proeng.2015.08.374.

Ko, B.C., Kim, H.H. and Nam, J.Y. 2015. Classification of potential water bodies using Landsat 8 OLI and a combination of two boosted random forest classifiers. *Sensors* 15(6):13763-13777, doi:10.3390/s150613763.

Koroglu, A., Ranasinghe, R., Jiménez, J.A. and Dastgheib, A. 2019. Comparison of coastal vulnerability index applications for Barcelona Province. *Ocean and Coastal Management* 178:104799, doi:10.1016/j.ocecoaman.2019.05.001.

Koulibaly, C.T. and Ayoade, J.O. 2021. The application of GIS and remote sensing in a spatiotemporal analysis of coastline retreat in Rufisque, Senegal. *Geomatics and Environmental Engineering* 15(3):55-80, doi:10.7494/geom.2021.15.3.55.

Lubis, S.M. 2011. Coastal Management. Institut Teknologi Bandung, Indonesia (*in Indonesian*).

Marfai, M.A. 2014. Impact of sea level rise to coastal ecology: a case study on the northern part of Java Island, Indonesia. *Quaestiones Geographicae* 33(1):107-114, doi:10.2478/quageo-2014-0008.

Marfai, M.A., Almohammad, H., Dey, S., Susanto, B. and King, L. 2007. Coastal dynamic and shoreline mapping: multi-sources spatial data analysis in Semarang Indonesia. *Environmental Monitoring and Assessment* 142(1-3):297-308, doi:10.1007/s10661- 007-9929-2.

Mujabar, P.K. and Chandrasekar, N. 2013. Shoreline change analysis along the coast between Kanyakumari and Tuticorin of India using remote sensing and GIS. *Arabian Journal of Geosciences* 6:647-666, doi:10.1007/s12517-011-0394-4.

Mutaqin, B.W. 2017. Shoreline changes analysis in Kuwaru coastal area, Yogyakarta, Indonesia: an application of the digital shoreline analysis system (DSAS). *International Journal of Sustainable Development and Planning* 12(7):1203-1214, doi:10.2495/SDP-V12-N7-1203-1214.

Nassar, K., Mahmod, W.E., Fath, H., Masria, A., Nadaoka, K. and Negm, A. 2019. Shoreline change detection using DSAS technique: case of North Sinai coast, Egypt. *Marine Georesources & Geotechnology* 37(1):81-95, doi:10.1080/1064119X.2018.1448912.

Nath, A., Koley, B., Saraswati, S., Bhatta, B. and Ray, B.C. 2021. Shoreline change and its impact on land use pattern and *vice versa*: a critical analysis in and around Digha area between 2000 and 2018 using geospatial techniques. *Pertanika Journal of Science and Technology* 29(1):331-348, doi:10.47836/pjst.29.1.19.

Nhan, N.T., Tung, N.X., Anh, B.T.B. and Thanh, N.X. 2018. Application of remote sensing, GIS and digital shoreline analysis system (DSAS) to assess the changes of the Red River Bank in the area from Son Tay to Gia Lam (Hanoi). *Journal of Marine Science and Technology* 18(3):269-277, doi:10.15625/1859-3097/18/3/11028.

Nugraha, I.N.J., Karang, I.W.G.A. and Dharma, I.G.B.S. 2017. Study of coastline change rate on the southeast coast of Bali using Landsat satellite imagery (case study of Gianyar and Klungkung Regencies). *Journal of Marine and Aquatic Sciences* 3(*2*):204-214, doi:10.24843/jmas.2017.v3.i02.204-214 (*in Indonesian*).

Passeri, D.L., Hagen, S.C., Medeiros, S.C., Bilskie, M.V., Alizad, K. and Wang, D. 2015. The dynamic effects of sea level rise on low-gradient coastal landscapes: a review. *Earth's Future* 3:159-181, doi:10.1002/2015EF000298.

Pendleton, E.A., Thieler, E.R. and Williams, S.J. 2010. Importance of coastal change variables in determining vulnerability to sea- and lake-level change. *Journal of Coastal Research* 261:176-183, doi:10.2112/08-1102.1.

Rumkorem, O.L.Y., Kurnia, R. and Yulianda, F. 2019. Association between coral community cover with coral reef fish at east coast of Biak Island, Biak Numfor Regency. *Jurnal Ilmu dan Teknologi Kelautan Tropis* 11(3):615-625, doi:10.29244/jitkt.v11i3.23375 (*in Indonesian*).

Rumpaidus, G.A., Putra, A.M. and Widyatmaja, I.G.N. 2019. Strategy for developing tourism destinations in Biak Numfor Regency, Papua Province. *Jurnal Kepariwisataan dan Hospitalitas* 3(2):22-42, doi:10.24843/JKH.2019.v03.i02.p03 (*in Indonesian*).

Ryabchuk, D., Spiridonov, M., Zhamoida, V., Nesterova, E. and Sergeev, A., 2012. Long term and short-term coastal line changes of the Eastern Gulf of Finland. Problems of coastal erosion. *Journal of Coastal Conservation 16*(3):233-242, doi:10.1007/s11852-010-0105-4.

Saad, R., Gerard, J.A. and Gerard, P. 2021. Detection of the shoreline changes using DSAS technique and remote sensing: a case study of Tyre Southern Lebanon. *Journal of Oceanography and Marine Research* 9(11):1000004.

Setyawana, F.O., Sari, W.K. and Aliviyanti, D. 2021. Analysis of coastline change using digital shoreline analysis system in Kuala Pesisir District, Nagan Raya Regency, Aceh. *Journal of Fisheries and Marine Research* 5(2):368-377, doi:10.21776/ ub.jfmr.2021.005.02.22 (*in Indonesian*).

Shuhendry, R. 2004. Coast Abrasion in Bengkulu City Coastal Territory: Analysis Cause Factor and Concept of Handling. Universitas Diponegoro, Semarang (*in Indonesian*).

Tablaseray, V.E., Pairin, M.R.A., Fakdawer, N. and Hamuna, B. 2018. Mapping of mangrove distribution and density in eastern coastal of Biak Island, Papua using Landsat 8 satellite imaginary. *Jurnal Perikanan dan Kelautan* 8(1):31-39, doi:10.33512/jpk.v8i1.3682 (*in Indonesian*).

Thieler, E.R. and Hammar-Klose, E.S.1999. National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast. U.S. Geological Survey Open-File Report 99-593. United States Geological Survey, Woods Hole, Massachusetts.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L. and Ergul, A. 2009. Digital Shoreline Analysis System (DSAS) version 4.0, An ArcGIS extension for calculating shoreline change. U.S. Geological Survey Open-File Report 2008-1278.

Xu, H. 2006. Modification of normalized difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing* 27(14):10-12, doi:10.1080/01431160600589179.

Yulianto, F., Suwarsono, Maulana, T. and Khomarudin, M.R. 2019. The dynamics of shoreline change analysis based on the integration of remote sensing and geographic information system (GIS) techniques in Pekalongan coastal area, Central Java, Indonesia. *Journal of Degraded and Mining Lands Management* 6(3):1789-1802, doi:10.15243/jdmlm. 2019.063.1789.

Zonkouan, B.R.V., Bachri, I., Beda, A.H.Z. and N'Guessan, K.A.M. 2022. Monitoring spatial and temporal scales of shoreline changes in Lahou-Kpanda (Southern Ivory Coast) using Landsat data series (TM, ETM+ and OLI). *Geomatics and Environmental Engineering* 16(1):145-158, doi:10.7494/geom.2022.16.1.145.