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Mapping shoreline changes using Landsat Imagery at Pemalang, Central Java Province, Indonesia

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Abstract. Pemalang Regency possess sloping geographical with shallow waters, it's potential to increase the area for pond fisheries and coastal tourism. This utilization causes changes in the coastline, which influenced by mankind and natural factors. The study aims to map shoreline changes in Pemalang, Central Java from year 2007-2022 using imagery of Landsat 7 ETM+ and Landsat 8 OLI/TIRS. The Digital Shoreline Analysis System (DSAS) method was performed to calculate rate of change statistics for a time series of shoreline vector data. This method uses parameters, including baselines, shorelines, and transects. The DSAS results in the year 2007-2022 shoreline change (NSM) and the 15-year mean shoreline change (EPR). All subzones occurred abrasion. Subzone D2 occurred greatest abrasion (-442.43 m). Subzones undergoing accretion include A1, A3, B1, B3, C2, C3, D1, D2, E2, and E3. The largest accretion occurs in A3 (333.05 m). Pemalang Beach in the year 2007-2022 occurred a change in coastline dominated by abrasion. The largest abrasion is in A3 (-2.39 m/year) and the smallest is in A2 (-1.89 m/year). The abrasion factors are the sloping beach, land use as tourist area, mangroves that are not maintained, and the flooding in May 2022. The changes in the coastline that have occurred are severe up to very severe.

1 Introduction

Indonesia so far is the country largest archipelagic country in the world which have the number of islands and the large area of the island, are around 17,508 islands. With the large number of islands, the length of the coastline of Indonesia reaches about 81.000 km. This makes Indonesia as the country with the second longest coastline after Canada [1]. Coastal areas where land and sea meet. Changes in coastal areas are due to land activity and also ocean activity. Land activities that affect coastal areas such as sedimentation and also input from fresh water flows. Coastal areas are also influenced by ocean activities such as waves, tides and wind [2].

The coastline is an imaginary line that is formed and is the boundary between sea water and land and this line changes according to tidal conditions. Changes in coastlines are certain, both temporary changes and permanent changes over a certain period of time due to abrasion

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and accretion. There are several ways to determine the coastline, namely the coastline at high tide, the coastline at average water, and the coastline at low water [3]. It is important to understand coastlines changes for environmental protection and country development. Coastline information is very important for further studies, especially in coastal area management. Pemalang Regency has sloping geographical conditions and has shallow waters. This shallow water area could be utilized for various regional improvements, especially in the economic activity. The geographical conditions of the Pemalang coast have the potential to be used as fish ponds and in the tourism sector.

Coastline changes are influenced by two factors, namely human factors and natural factors [4]. Naturally, coastlines are influenced by tides, wind, waves and sedimentation. Human factors that influence changes in coastlines, namely construction and cutting down of coastal protective plants. To maximize coastal area management plans, it is necessary to conduct research on changes in coastlines so that we can determine the impact of development on the coastal environment [5]. Changes in coastlines can be identified using remote sensing technology by processing satellite images which have comprehensive recording of objects [6].

One of the methods used to determine changes in coastlines by using the Digital Shoreline Analysis System (DSAS) [7], conducted research on coastline changes using Landsat imagery in Bali Province. The DSAS method able to calculate the extent of coastline changes. Information about coastline is important to know because coastlines have dynamic or changeable properties.

2 Materials and methods

2.1 Time and research location

The research was carried out in January - June 2023. Field observations were conducted from 09 - 16 August 2023 on the coast of Pemalang Regency, Central Java, Indonesia (Fig.1). Data processing and analysis were carried out at the Marine Remote Sensing Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University, Dramaga Campus, Bogor, West Java, Indonesia.

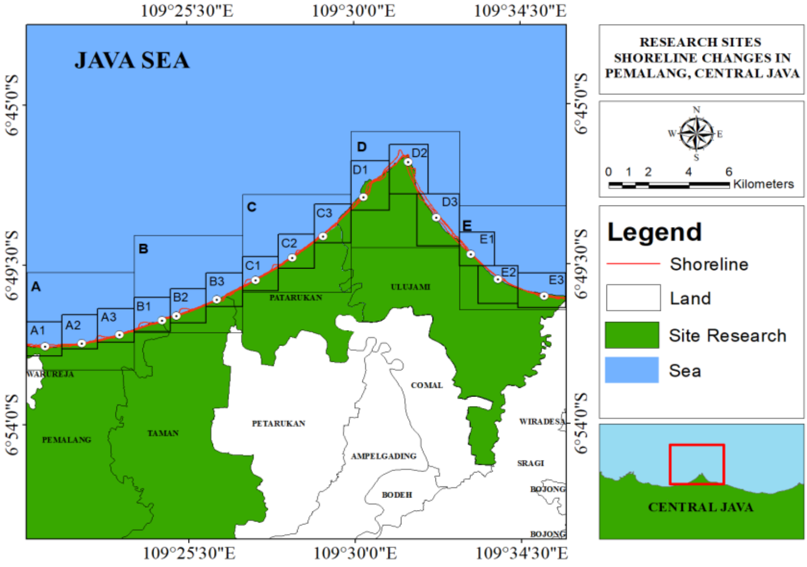


Fig. 1 The research location at coast of Pemalang, Central Java, Indonesia

2.2 Data and tools

The tools used in this research include a laptop that has the Arcgsis 10.8, WRPlot View, Ocean Data View 4, Google Earth, Microsoft Word and Microsoft Excel applications installed. The tools used for field observations are the Global Positioning System (GPS) for taking Ground Control Points (GCP) using marking methods and field documentation using cameras, as well as writing tools. Those materials used are shown in Table 1.

Table 1 Sources of Information and Data Acquisition

Parameter	Data Sources	Resolution	Acquisition Time
Field data	Field data	-	August 2023
Landsat 8 OLI/TIRS	Earthexplorer.usgs.gov	30 m	06 October 2007
Landsat 8 OLI/TIRS	Earthexplorer.usgs.gov	30 m	22 August 2017
Landsat 8 OLI/TIRS	Earthexplorer.usgs.gov	30 m	18 August 2022
Wind	cds.climate.copernicus.eu	0.083º	2007-2022
Current	marine.copernicus.eu	0.083º	2007-2021
Tides	tides.big.go.id	180 m	2007-2022
*Bathymetry	Indonesia Geospatial Information Agency	BATNAS	-

* Only to display depth contours (Isodepth)

2.3 Data processing and analysis

Data processing and analysis includes several stages. The first stage done was radiometric correction using the Top of Atmosphere (TOA) method. Radiometric correction aims to reduce image scattering so that it will produce image sharpening. Next, return the image pixel value called as digital number (DN) to the reflection value on the earth's surface (at surface reflectance). The method used was called Dark Object Subtraction (DOS).

Stages of shoreline extraction in Landsat 8 OLI/TIRS images using the shoreline extraction technique referring to [8], utilizing the Normalized Difference Vegetation Index (NDVI) algorithm [9]. The steps for determining NDVI in this technique use a composite of the red band and near infrared (NIR) to determine the level of greenness and classification of vegetation areas. This index value has a value range of -1 to 1 [10]. The NDVI algorithm used to determine the level of greenness and classification of vegetation areas as:

$$NDVI = (NIR - red) / (NIR + red) \qquad (1)$$

NDVI values were classified into 2 classes, namely land and seawater. The next stage was shore boundary, a feature for creating coastlines based on the boundaries between land and seawater. The final stage was to overlay the coastline of year 2007, 2017 and 2022.

Tidal data was used to correct the image to obtain the true coastline. Image data was corrected with tidal data to reduce errors due to differences in tidal conditions when recording satellite images. Image shoreline correction was determined by the difference between the water surface position at the time of image recorded (s) and the datum divided by the slope of the beach (α). The illustration of coastline corrections to tides could be seen in (Fig. 2). Coastline shifts (r) could be determined using the formula below

$$r = \ s \ / \ tan \ \alpha \qquad (2)$$

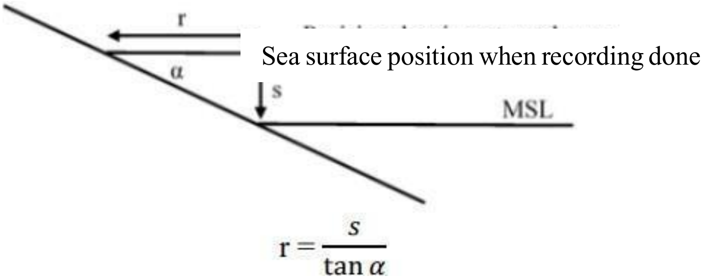


Fig. 2 Illustration of coastline corrections to tides

Temporal analysis of coastline changes was carried out using the DSAS method, a software application that is freely available and works within the Environmental Systems Research Institute (ESRI), a Geographic Information System (GIS) software. DSAS calculates rate of change statistics for coastline vector data time series [11]. This program requires several parameters to measure the rate of change in shorelines like baseline, shoreline and transect. The parameters used must be connected to one geodatabase which has an attribute in the form of an ID as a link to other parameters.

Calculation of shoreline changes was based on the intersection between shoreline and transect. Measuring the rate of change in coastlines uses End Point Rate (EPR) calculations in meter/year, and Net Shoreline Movement (NSM) in meters (m). EPR is a fairly simple method for measuring coastline changes or estimating them. The NSM method could measure the difference in distance between the previous coastline and the current coastline. The rate of change was obtained from the intersection of one point (intersect point) with another point divided by the processing time of the point change that occurred. Coastline changes that occur are grouped into 8 categories as shown in Table 2.

Table 2 Matrix of coastal changes categories

No	Criterion	Categories
1	Less then -10.00	Very severe abrasion
2	-9.99 - -5.00	Serious abrasion
3	-4.99 - -2.00	Medium abrasion
4	-1.99 – 0.00	Low abrasion
5	0.00 – 1.99	Low accretion
6	2.00 – 4.99	Medium accretion
7	5.00 – 9.99	Serious accretion
8	Greater than 10.00	Very severe accretion

3. Result and Discussion

3.1 General condition of the beaches in Pemalang

The Pemalang coast have a height of between 1-5 meters above sea level. The coast of Pemalang is used for fish ponds, natural tourism, fishing settlements and river estuaries. Pemalang Beach generally have a rocky beach and sandy beach geomorphology type. Based on these conditions, beaches characterized by sand are more susceptible to shoreline changes than rocky beaches. This is because sandy beaches are composed of sand material. Sand particles have dynamic properties and tend to be more easily blown away by wind and waves. Therefore, changes in coastlines often occur on sandy beaches at Pemalang regency.

3.2 Bathymetri on Pemalang Beach

The coast of Pemalang, Central Java has a sloping depth contour. The contours on the Pemalang coast show a contour pattern that is parallel to the coastline in areas near the beach. However, offshore areas have a basin contour pattern. The depth of the waters on the coast of Pemalang ranges from 1 – 40 m, which indicates that the waters will get deeper towards the offshore. An overview of the depth profile of the Pemalang coast, Central Java can be seen in (Fig. 3). The sloping bathymetry of the Pemalang coast and shallow waters cause sediment resuspension which is influenced by wind, waves and tides [2].

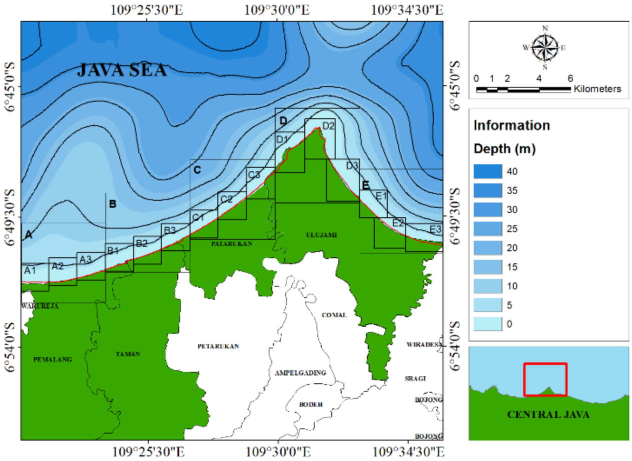


Fig. 3 Bathymetri on Pemalang Beach

3.3 Wind direction and wind speed

Wind direction and speed conditions from 2007 to 2022 on the Pemalang Coast, Central Java are shown in the form of a wind rose (Fig. 4) (a) west season (b) east season. The wind in the west season moves from the Asian continent towards the Australian continent, the direction of the wind moves from east to west. In the west season wind moves at speed of 0.5 m/s to 11.00 m/s and the average speed this season around 4.56 m/s. The wind in the east season moves from the Australian continent towards the Asian continent, the direction of the wind moves from west to east. In the east season it moves at a speed of 0.5 m/s to 9.5 m/s and the average speed this season around 2.93 m/s.

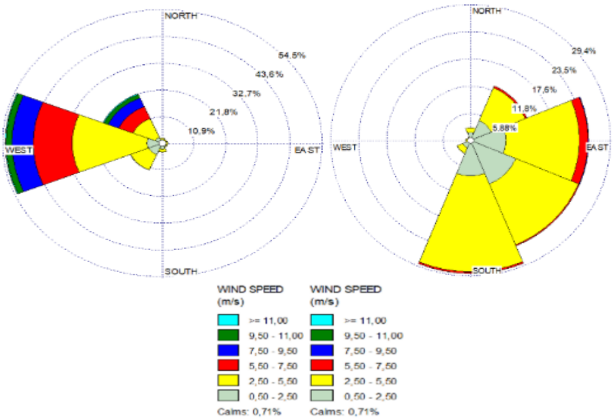


Fig. 4 Wind rose on the Pemalang Coast, Central Java 2007-2022

The magnitude of the wind influences the occurrence of currents which cause the movement of water masses from one place to another, which will trigger changes in the coastline [12]. Tabulation of wind distribution frequencies on the Pemalang Coast could be in Table 3.

Table 3 Percentage of wind direction and speed in Pemalang, Central Java

Wind direction	Wind speed (m/s)						
	0.00-2.50	2.50-5.50	5.50-7.50	7.50-9.50	9.50-11.00	≥ 11.00	Total
North	0.02	0.01	0.00	0.00	0.00	0.00	2.53
Northeast	0.03	0.04	0.00	0.00	0.00	0.00	7.51
East	0.05	0.08	0.01	0.00	0.00	0.00	13.52
Southeast	0.06	0.07	0.00	0.00	0.00	0.00	13.52
South	0.05	0.11	0.00	0.00	0.00	0.00	16.62
Southwest	0.04	0.04	0.00	0.00	0.00	0.00	7.61
West	0.03	0.13	0.07	0.04	0.01	0.00	27.19
Northwest	0.02	0.04	0.03	0.02	0.01	0.00	11.50

3.4 Tidal conditions

Tides were needed to see the magnitude of the daily tides and determine the type of tides in the Pemalang area. Tides were shifts in sea level that occur due to the gravity of the sun and moon. Tidal data processed for 15 days was used to correct tides images to show the corrected coastline and graphs of tidal height values which correspond to Mean Sea level (MSL). The type of tides in Pemalang waters is mixed semi-diurnal. This was based on the calculation of the Formzahl value, a value of 1.17 is obtained which describes the Pemalang coast having tides that form two highs and two lows in a day and sometimes two highs and one low or vice versa, one high and two lows in a day [13]. Tidal conditions at Pemalang waters shown in (Fig.5).

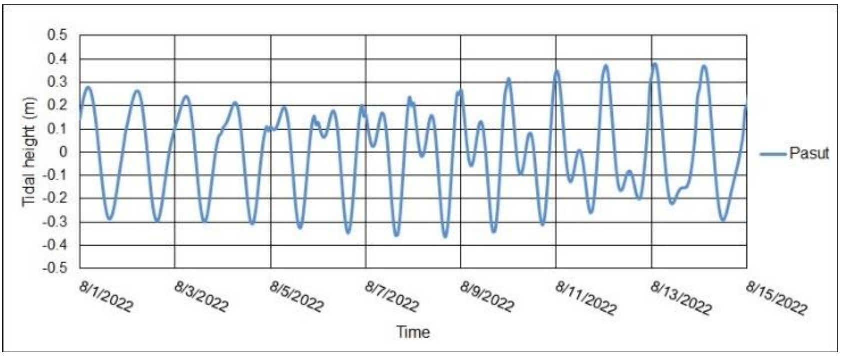
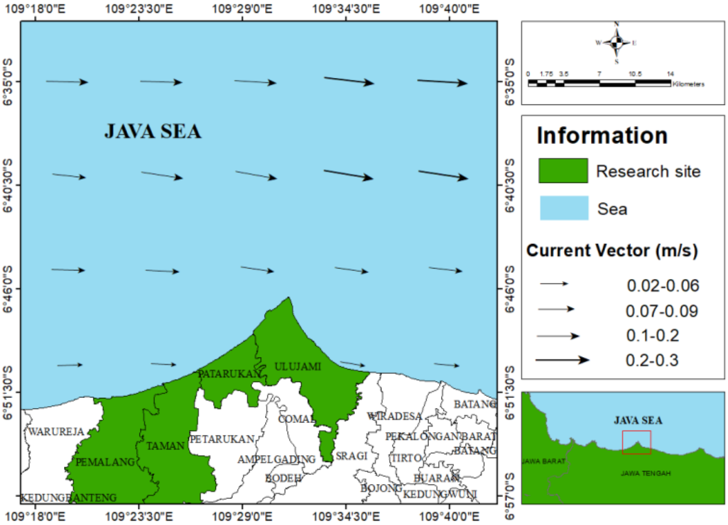


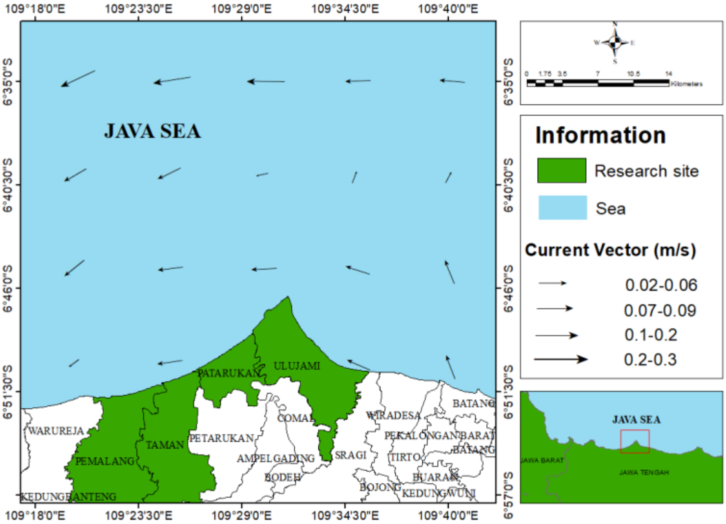
Fig. 5 Tidal Conditions of Pemalang waters, Central Java

3.5 Sea current

The sea surface currents on the coast of Pemalang, Central Java show sea current movements. Currents in the western monsoon (December–February) move from west to east, with an average speed of 0.08 m/s. Currents in the eastern monsoon (June-August) move from east to southwest, with an average speed of 0.03 m/s. The Pemalang coastal current moves parallel to the coastline (longshore current). The movement of currents influences changes in coastlines due to the movement and deposition of sediment [14]. This movement and deposition of sediment will cause abrasion due to the sediment moves to a location where the influence of the current will add sediment to other places, causing accretion [15].



(a)



(b)

Fig. 6. Surface currents in western monsoon (a) and eastern monsoon (b)

3.6 The rate of change in coastlines

Changes in the coastline in Pemalang regency, Central Java generally experience abrasion and accretion (Fig. 7). Beach abrasion is the erosion of beaches caused by destructive ocean waves and ocean currents. Meanwhile, accretion is a change or addition to the coastline towards the open sea due to sedimentation processes from land or river flows [16]. The coastline changes were obtained from analysis of coastline extraction from year 2007 to 2022 by overlaying method. Coastline changes were analyzed using the DSAS method by calculating the magnitude of changes that occurred over 15 years (m) and calculating the average change each year (m/year).

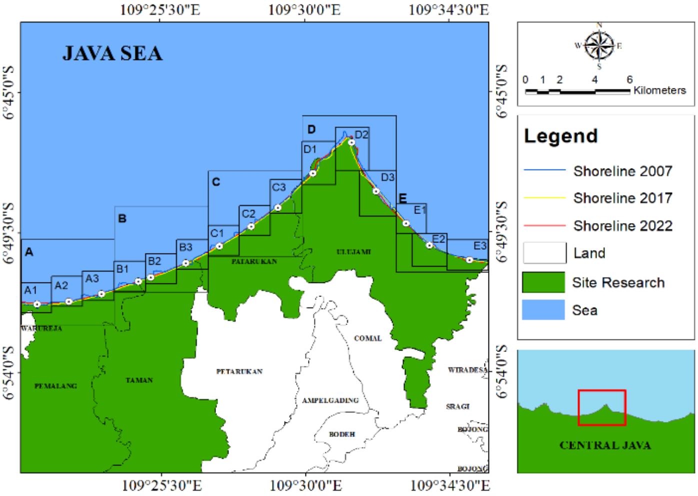


Fig. 7 Charts Changes in coastline in Pemalang, Central Java 2007-2022

Changes in the coastline in Pemalang using satellite imagery are changes detected by satellite imagery with a value greater than the spatial resolution of the image used, namely

30 m (Landsat 8 OLI/TIRS). The coastline change (NSM) value is processed based on the previous coastline (2007) and the latest coastline (2022). The average coastline change (EPR) value is obtained from the coastline change divided by the time span (15 years).

The process of changing the coastline in Pemalang (Fig.8) dominated by reduction of the coastline (abrasion) compared to the addition of coastline sedimentation (accretion). This is based on the shifting of the coastline, which causes a greater abrasion process compared to the accretion process. Areas experiencing changes in abrasion with a value of more than 1 pixel (Table 4) occurred in all observation zones including Pemalang District (A), Taman District (B), Patarukan District (C), and Ulujami District (D and E). Areas experiencing accretion changes occur in almost all observation subzones. Areas that did not experience accretion include A1 in Pemalang District, B2 in Taman District, C1 in Patarukan District, D3 in Ulujami District, and E1 in Ulujami District. DSAS analysis of changes in coastline in Pemalang District (Zone A) experiencing abrasion and accretion. Coastline changes in Sub Zone A1 experienced maximum abrasion of -2.03 m/year and experienced maximum accretion of 22.46 m/year. Coastline changes in Sub Zone A2 experienced maximum abrasion of -14.02 m/year, but did not experience shoreline changes in the form of accretion. Sub Zone A3 experienced maximum abrasion of -2.39 m/year and experienced maximum accretion of 22.46 m/year. Abrasion in Pemalang District (Zone A) occurs due to the sloping type of beach, sandy material and the absence of breakwaters. So, it is easily exposed to abrasion by currents and wind. The accretion that occurred in Pemalang regency occurred due to the increase in area making by the government. According to Mr. Muslim (a local resident), this was done around 2010 with the addition of a provincial road, so that this expanded area was used by local residents to open stalls around the beach and make the beach area for tourist destination. Apart from that, this addition to the beach was used to build a breakwater which was used as a wave breaker to prevent severe abrasion. Apart from that, the presence of groins around the beach was able to prevent sedimentation so that beach growth occurs. This is in accordance [17], who stated that groins on Pemalang beach were able to withstand abrasion because they can capture sediment to add to the coastline.

Observations in Taman District (Zone B) experienced changes in abrasion and accretion (Fig. 8). Subzone B1 experienced maximum abrasion of -13.05 m/year and experienced maximum accretion of 4.3 m/year. Subzone B2 experienced maximum abrasion of -19.46 m/year, but did not experience accretion. Subzone B3 experienced maximum abrasion of -10.31 m/year and experienced maximum accretion of 10.77 m/year. Abrasion in Taman District was caused by the absence of breakwaters, sloping beach conditions and parallel currents. This was in accordance with [18] which states that parallel currents occur due to the influence of winds which causes waves to break. The absence of a breakwater results in abrasion caused by parallel currents. Suspended sand material will be more easily carried by currents. Accretion in Taman District occurred due to the additional land area taken from the sea which was used by local residents for shrimp farming activities. Apart from that, the condition of rocky beaches can withstand the rate of abrasion because the material was not easily broken up and moved by parallel currents.

Patarukan District (Zone C) experienced coastline changes in the form of abrasion and accretion (Fig. 8). Subzone C1 experiences maximum abrasion of -13.7 m/year but does not experience shoreline changes in the form of accretion. Subzone C2 experienced maximum abrasion of -11.18 m/year and experienced maximum accretion of 2.44 m/year. Subzone C3 experienced maximum abrasion of -9.29 m/year and experienced maximum accretion of 5.72 m/year. DSAS analysis results observed that Ulujami District (Zone D) experienced abrasion and accretion. The accretion that occurs was used to create pond land, tourist areas, and was used by local residents to open businesses around the coast. Abrasion in Patarukan District was caused by the absence of a breakwater, a type of beach that was sloping, so that sediment in this area can easily move to other places resulting in abrasion in Patarukan District.

Zones D and E were included in the Ulujami District which experienced quite large abrasion (Fig.8). Subzone D1 experienced maximum abrasion of -14.62 m/year and experienced maximum accretion of 15.87 m/year. Subzone D2 experienced maximum abrasion of -29.84 m/year and experienced maximum accretion of 19.3 m/year. Subzone D3 experienced maximum abrasion of -17.82 m/year but did not experience changes to the coastline in the form of accretion. Subzone E1 experienced changes in coastline in the form of maximum abrasion of -11.12 m/year, but did not experience accretion. Subzone E2 experienced changes in coastline in the form of maximum abrasion of -7.48 m/year and experienced maximum accretion of 3.03 m/year. Subzone E3 experienced changes in coastline in the form of maximum abrasion of -10.22 m/year and experienced maximum accretion of 3.47 m/year. The abrasion that occurred in Ulujami District (Zones D and E) was caused by several factors like bathymetry, currents, wind and also human factors. Human factors such as illegal felling of pine trees, which were used for building materials, have resulted in this area being exposed to abrasion. The condition of the sloping beach, the type of sandy sediment and the absence of breakwaters result in the absence of barriers so that waves break on the shoreline.

Human activities in Pemalang, Central Java influence changes in the coastline. Illegal felling of pine trees used for building materials results in no windbreaks and waves breaking on the beach. The additional area taken from the sea is to increase the land on the beach which is used for beach tourism which local residents use to build stalls around the beach. The economic sector from the addition of coastal areas is also used by local residents to open ponds and plant mangroves. The ROB flood that occurred in Pemalang caused quite large abrasion. This is in accordance with [19], that ROB floods occur due to damage to coastal embankments and coastal erosion. So, the retreat of the coastline causes water to enter the land and pond areas are permanently inundated by sea water.

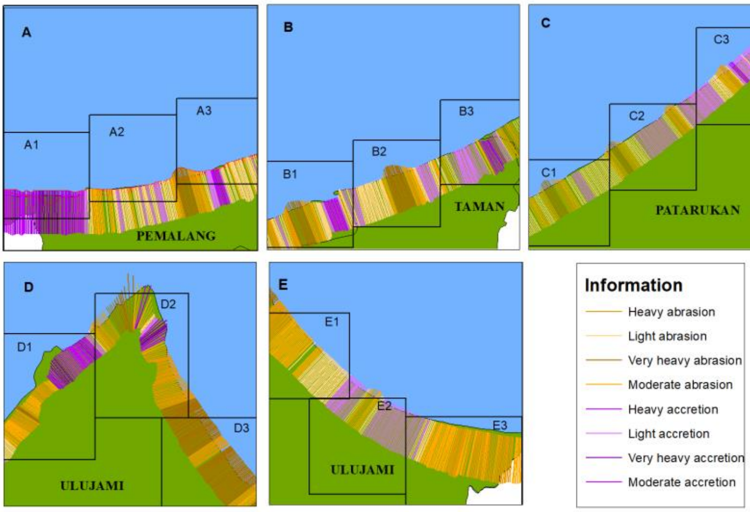


Fig. 8 Shoreline changes in 2007-2022 in Zones A, B, C, D, and E

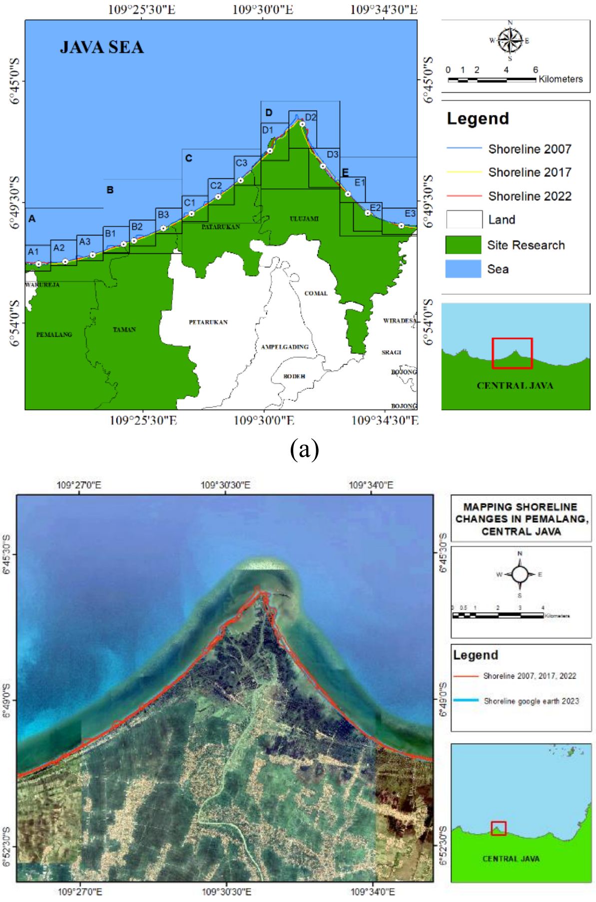
Table 4 Coastline changes >1 pixel (30m) in 2007-2022

Sub zone	Number of transcect		Shoreline changes (m)				Average shoreline changes (m/year)			
			abrasion		accretion		abrasion		accretion	
	abrasion	accretion	min	max	min	max	min	max	min	max
A1	10	83.33	-30.07	-30.07	33.17	333.05	-2.03	-2.03	2.24	22.46
A2			-28.1	-207.95	0	0	-1.89	-14.02	0	0
A3			-35.38	-214.6	30.02	333.05	-2.39	-14.47	2.02	22.46
B1	26.33	5.67	-30.41	-193.54	42.95	63.79	-2.05	-13.05	2.9	4.3
B2			-30.04	-288.56	0	0	-2.05	-19.46	0	0
B3			-32.54	-152.84	50.15	159.76	-2.19	-10.31	3.38	10.77
C1	16.33	9	-31.54	-203.1	0	0	-2.13	-13.7	0	0
C2			-34.96	-165.73	30.02	36.13	-2.36	-11.18	2.02	2.44
C3			-32.74	-137.78	30.72	84.82	-2.21	-9.29	2.07	5.72
D1	75.67	18.33	-30.35	-216.85	34.32	235.26	-2.05	-14.62	2.31	15.87
D2			-32.98	-442.43	49.28	286.18	-2.22	-29.84	3.32	19.3
D3			-34.15	-264.23	0	0	-2.3	-17.82	0	0
E1	44.33	2.67	-30.32	-164.87	0	0	-2.04	-11.12	0	0
E2			-31.87	-110.88	30.14	44.99	-2.15	-7.48	2.03	3.03
E3			-30.37	-151.59	31.31	36.67	-2.05	-10.22	2.11	2.47

3.7 Shoreline changes with Landsat 8 and Google Earth Images

Coastline changes are identified further so that accurate results could be obtained by validating the processed Landsat 8 images with Google Earth high resolution images. This was obtained from the results of processed Landsat imagery which was then overlaid with Google Earth digitization results. The location validation between the processed Landsat images could be done. The average longitude validation results produce a value of 0.0561° and the average latitude validation results produce a value of 0.0182°. Validation of longitude and latitude produces a value of 0.0590°(Table 5), indicating that it is not significantly different from the results of processed Landsat imagery with Google Earth. This was in accordance with research results of [19] which states that, if standard deviation value gets smaller, then the measurements made have good accuracy. But, if standard deviation to large value, so the level of accuracy of the measurement results is poor (Table 5).

The difference between Landsat 8 imagery and Google Earth was clearly visible from Fig. 9 (a) and (b). Landsat 8 image resolution has a spatial resolution of 30 m and Google Earth's spatial resolution has a high resolution of 5 m per pixel. The advantage of Google Earth, apart from having high resolution was that Google Earth could see the latest scene like water conditions, residential areas, public roads, it can see also the sea because it can visualize conditions in the sea [20].



(a)

(b)

Fig. 9 Coastline Changes using Landsat 8 (a) and google earth (b)

Table 5 Standard deviation of landsat imagery and google earth

No		Landsat Imagery			*Google Earth*	Deviation	Standard deviation
		2007	2017	2022			
1	Longitude (x)	109.362	109.352	109.361	109.592	0.1172	0.0561
2	Latitude (y)	-6.864	-6.862	-6.842	-6.841	0.1108	0.0182
Standard deviation (x,y)							0.0590

4 Conclusions

Pemalang Beach, Central Java, during 2007-2022 have coastline changes which was dominated by abrasion. The greatest abrasion occurred at subzone D2 (Ulujami District) at -29.84 m/year. Meanwhile, the smallest abrasion occurred in subzone A1 (Pemalang District) at -2.03 m/year. The largest accretion occurred in subzones A1 and A3 (Pemalang District) about 22.46 m/year. But the smallest accretion occurred in subzone C2 (Patarukan District) at 2.44 m/year. Several things influence abrasion as the type of beach that is sloping, land use, the condition of mangroves that are not maintained, and the phenomenon of flooding in May 2022. The changes in the coastline that occur are severe to very severe.

References

1. S. Setyowati. *Studi Perubahan Garis Pantai Pulau Untung Jawa Kepulauan Seribu DKI Jakarta* [skripsi]. Jakarta, Universitas Islam Syarif Hidayatullah, (2016)
2. Darmiati, IW, Nurjaya, AS Atmadipoera, J. ITKT. **12**(1), 211-222 (2020)
3. G. Winarso, H. Joko, S. Arifin, J P Jauh. **6**(2009), 65-72 (2019)
4. M.F. Istiqomah. *Analisis Perubahan Garis Pantai Kabupaten Jembrana dengan Menggunakan Citra Satelit Landsat 8* [skripsi]. Jakarta, Universitas Islam Syarif Hidayatullah (2017)
5. Sakka, M. Purba, I W Nurjaya, H Pawitan, V P Siregar, J. ITKT. **3**(2), 112-126 (2011)
6. M. Dewi. *Perubahan garis pantai menggunakan citra spot multitemporal dan metode analitik di daerah Tanjung Layang Kecamatan Sungailiat Provinsi Kepulauan Bangka Belitung* [skripsi]. Palembang, Universitas Sriwijaya (2016)
7. N.M.N. Natih, R.A. Pasaribu, M.S. Sangadji, E.E. Kusumaningrum, in Earth Enviromental Science. **429**, 1-6 (2020)
8. E.R Thieler, E.A Himmelstoss, J.L. Zichichi, A. Ergul. *The Digital Shoreline Analysis System (DSAS) Version 4.0- an ArcGIS Extension for Calculating Shoreline Change.* U.S. Geological Survey Open-File Report. 2008-1278 (2009)
9. J.W Scott, L. Moore, W.M. Harris, M.D. Reed, *Using the Landsat Enhanced Thematic Mapper Tasseled Cap Transformation to Extract Shoreline*.US: U.S Geological Survey Open-File Report. 2003-272 (2003)
10. G. Hazazi, Sasmito H, Firdaus HS, J Geodesi Undip. **8**(1), 19-27 (2019)
11. A.R. Setiabudi, T.I. Maryanto, J Online Institut Teknologi Nasional. **2**(2018), 42-50 (2018)
12. P.S. Dewi, H. Setiyono, G. Handoyo, S. Widada, D. Suryoputro, Indonesian J. of Oceanography. **2**(3), 233-242 (2020)
13. Suhaemi, S. Raharjo, Marhan, J. Sumberdaya Akuatik Indopasifik. **2**(1), 57-64 (2018)
14. A.W. Dwinanto, N.P. Purba, S.A. Harahap, M.L. Syamsudin, J. Perikanan dan Kelautan. **3**(2), 152-160 (2017)
15. M. Ukkas, J. Sumberdaya Perairan. **3**(1), 20-29 (2009)
16. F. Istiqomah, B. Sasmito, F.J. Amarrohman, J. Geodesi Undip. **5**(1), 78-89 (2016)
17. H. Ahdannabiel, S. Widada, Hariadi, J. Oseanografi. **6**(4), 650-658 (2017)
18. S. Widada, A. Ismanto, I.B. Priambodo, H. Siagian, J.l KT. **6**(9), 121-130 (2022)
19. A. Yuanita, A. Suprayogi, I. Hania'ah, J.l Geodesi Undip. **2**(2), 38-53 (2013)
20. I.R. Nur, Syamsidik, S. Syahreza, J. Rekayasa Elektrika. **1791**, 62-69 (2022)