Revista Geográfica de Chile Terra Australis, Vol.60 (2024) 17-26 ISSN 0719-9562

: https://doi.org/10.23854/07199562.2024601.mubarak

EXTRACTION OF LANCEOLATE IMAGERY FOR ANALYSIS OF MANGROVE EXTENT AND SHORELINE CHANGES

EXTRACCIÓN DE IMÁGENES LANCEOLADAS PARA EL ANÁLISIS DE LA EXTENSIÓN DE MANGLARES Y DE CAMBIOS EN LA LÍNEA DE COSTA

Mubarak[1,] Maellynia Mustofa[1], Efriyeldi[1], Rifardi[1], Romi Syahputra[2]

Abstract

This study aims to determine the area of Topang Island's mangrove forest, an area experiencing extreme line changes and the magnitude of the coastline change rate from 1991 to 2021 on Topang Island, Kepulauan Meranti Regency, Riau Province. The method used in this research is remote sensing and field survey. The data obtained were discussed descriptively. The results found that the calculation of wave height prediction on the coast of Topang Island was included in the low category with an average height of 0.12 meters. The research area is dominated by abrasion, based on visual observations, Topang Island has a type of peat and muddy beach. The area of mangroves on Topang Island from 2001 to 2021 saw a big change, either adding or reducing the area of mangroves. Topang Island experienced the worst abrasion in the eastern part with an average abrasion rate of 6.13 m/year, and accretion in the western part with an average accretion rate of 0.62 m/year.

Keywords: Mangrove, Shoreline change, abrasion and accretion, DSAS

Resumen

Este estudio tiene como objetivo determinar el área del bosque de manglares de la isla Topang, un área que experimenta cambios extremos en la línea y la magnitud de la tasa de cambio de la línea costera de 1991 a 2021 en la isla Topang, Kepulauan Meranti Regency, provincia de Riau. El método utilizado en esta investigación es la teledetección y el estudio de campo. Los datos obtenidos fueron discutidos de forma descriptiva. Los resultados encontraron que el cálculo de la predicción de la altura de las olas en la costa de la isla Topang se incluyó en la categoría baja con una altura promedio de 0,12 metros. El área de investigación está dominada por la abrasión; según observaciones visuales, la isla Topang tiene un tipo de playa de turba y barro. El área de manglares en la isla Topang de 2001 a 2021 experimentó un gran cambio, ya sea agregando o reduciendo el área de manglares. La isla Topang experimentó la peor abrasión en la parte oriental con una tasa de abrasión promedio de 6,13 m/año, y acreción en la parte occidental con una tasa de acreción promedio de 0,62 m/año.

Palabras Clave: Manglar, cambio de costa, abrasión y acreción, DSAS

(1) Department of Marine Science, HR. Soebrantas 12,5, Panam, Pekanbaru 28293, Indonesia
(2) Department of Physics, University Muhammadiyah Riau, KH. Ahmad Dahlan 88, Sukajadi, Pekanbaru 28156, Indonesia

INTRODUCTION

Mangrove forests are intertidal wetlands found along coastlines in most tropical, subtropical and warm climates, where they naturally serve as the first line of defense against flooding and erosion (Domonicis, 2023). Mangrove forests are tropical trees and shrubs that grow along coastlines, mudflats, and riverbanks in various parts of the world (Field, 1999; Wang et al., 2019). Mangrove forests are one of the most productive and biologically important ecosystems because they provide various goods and services to society, as well as provide benefits to coastal and marine systems (Giri et al., 2011b; Valiela et al., 2001; Wang et al., 2019). However, during the last two decades of the 20th century, around 35% of the world's mangroves have been lost, putting mangroves in jeopardy (Bosire et al., 2008; Valiela et al., 2001). Due to the harsh environment in the mangrove ecosystem, remote sensing (RS) has become an ongoing tool in the study of mangrove forests (Blasco et al., 2001; Kumardkk., 2013; Vaiphasa, 2006; Wang et al., 2019).

Indonesia itself is an archipelago that has a coastline reaching 108,000 km (Ministry of Maritime Affairs and Fisheries, 2019). The coastline is an important component in determining the boundaries of a country's territory and regional autonomy. This region is highly dynamic and continuously vulnerable due to natural and man-made disturbances (Bird, 2008; Jayakumar and Malarvannan, 2016; Muskananfola et al., 2020). Therefore, shoreline information is needed considering that coastlines are dynamic. The dynamic nature of the coastline makes it necessary to monitor the coastline by making periodic shoreline change maps. Natural disturbances are caused by tsunamis, storms, waves, currents, tides, erosion, accretion, and flooding, while human disturbances include the construction of breakwaters, groins, wharves, household and industrial waste, and recreational activities. Both natural and human factors have caused erosion and accretion which have resulted in shoreline changes both in the short and long term (Leatherman et al., 2003; Saranathan et al., 2011; Mahapatra et al., 2014; Poormima et al., 2015; Muskananfola et al. ., 2020).

Geographically, Meranti Islands Regency is located on the east coast of Sumatra Island, with a coast bordering a number of countries. The Meranti Islands have the potential to function as a cross-border gateway connecting mainland Riau with neighboring countries by sea.

Topang Island itself is located in Rangsang District, Meranti Islands Regency, Riau Province. Topang Island is one of the small islands in Indonesia. Topang Island has a land area of 2,900 Ha to 3,000 Ha, from 1990-2015 Topang Island has changed 272.52 ha (Wahyudi, 2017).
The government has tried various ways to deal with problems in coastal areas, such as planting mangroves, but it has not been successful.

Identification of coastal damage needs to be done to reduce the effects of damage or changes in coastal areas. The easiest indication of changes that occur in the coast is the phenomenon of changes in the coastline, resulting in increased coastal erosion and threats to people living in coastal areas.

The aim of the study was to analyze the size of the mangrove area on the coast of Topang Island and the areas that experienced shoreline changes on Topang Island from 1991 to 2021 and find out the magnitude of the rate of shoreline change on Topang Island.

MATERIALS AND METHODS

GENERAL CONDITION.

Topang Island is located in the Rangsang District, Meranti Islands Regency, Riau Province. Topang Island is to the south of Rangsang Island.

Astronomically, Topang Island is located between 0º45'29.000" North Latitude and 103º5'43.000" East Longitude. (Figure 1).

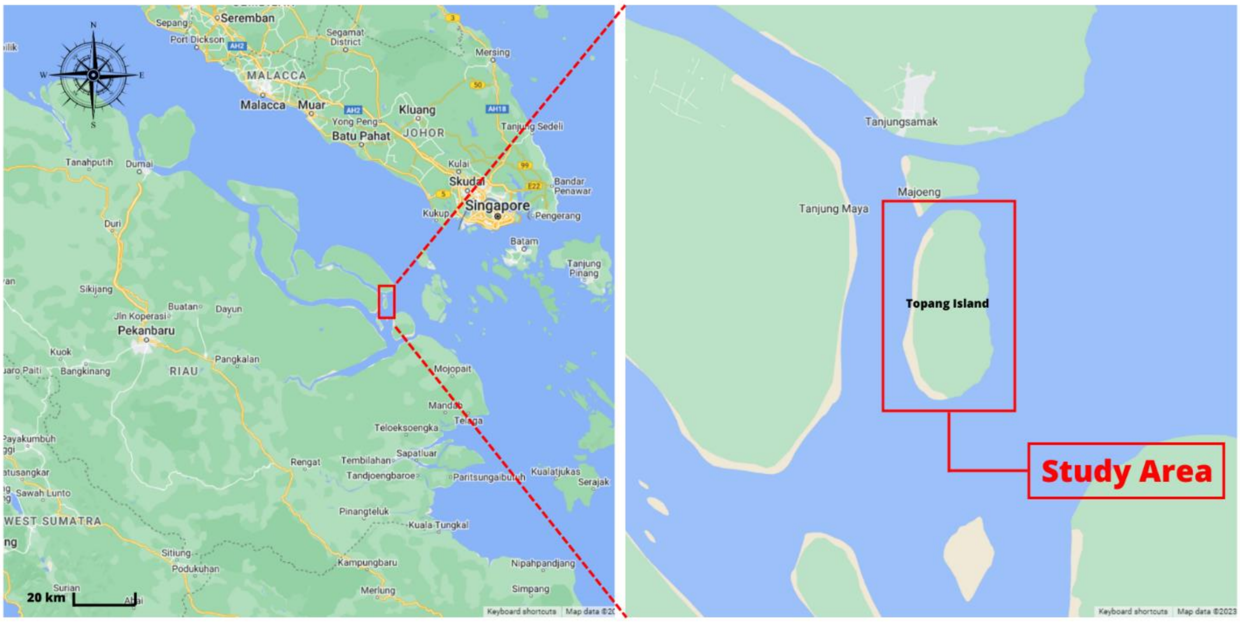


Figure 1. Map of Study Area

DATA COLLECTION.

In this research using several tools and materials, both used for field surveys and in analysing data. The tools used in the research are GPS, laptop, mobile phone, stationery. The software used is ArcGIS which has DSAS in it and Mike21.

SHORELINE CHANGE.

The materials used in the analysis of shoreline changes are Lansad satellite images in 1991, 1996, 2001, 2006, 2011, 2016, and 2021. The flow of this research begins with secondary data collection, data processing by digitising Lansad images after the coastline is obtained, then making a baseline as the beginning of the transect line, after the baseline is made, collecting all the digitised coastlines together in a special file, namely the geodatabase file. The baseline file and the shoreline file were put into the same folder, namely the geodatabase foder to start analysing shoreline changes and then making thematic maps (shoreline changes), the resulting thematic map was used as a reference for carrying out ground checks.

WAVE HEIGHT.

The material used to make wave height forecasts is wind data obtained from the Coperniccus website.

The downloaded wind data is then subjected to several corrections so that what is obtained is the assumed wind data that can cause waves at sea. After the wind data is corrected, the wind data is calculated to get wind speed, wave period and wave height. To see the graph output using Mike21.

MANGROVE AREA.

The material used to calculate the mangrove area is the result of colour composite (RG) band 564. Image cropping is done in areas where there is mangrove vegetation, then exported in excel form to obtain the area of mangrove vegetation.

RESULTS AND DISCUSSION

WAVE HEIGHT FORECASTING.

In forecasting wave height using wind direction and speed data. The results of the analysis of wind data blowing at sea level are presented in the form of a wind rose in January 2022 for 24 hours for the Topang Island area as shown in Figure 2. In the figure it can be seen that the radial lines are the direction of the wind, while each circle shows the direction of the wind. presentation of wind events in the measurement time period.

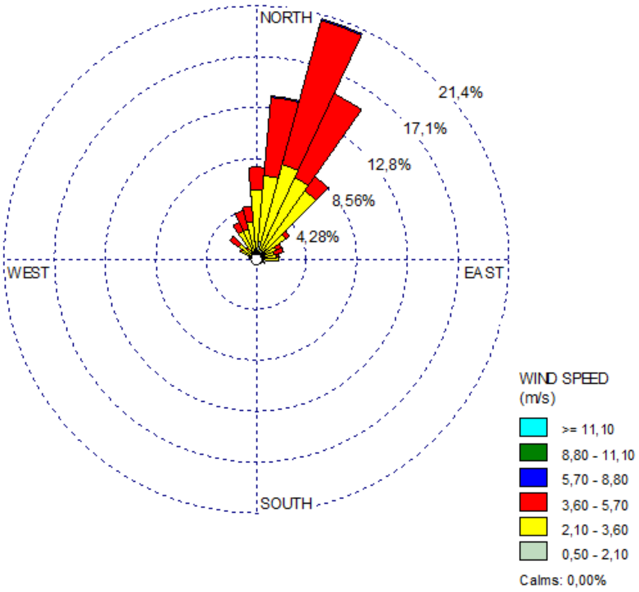


Figure 2. Windrose diagram

Based on the windrose diagram in Figure 2, the highest wind gusts according to the average wind speed are in the northern part with dominant speeds ranging from 3.60 to 5.70 m/s.

The wind that blows over the surface of the water will transfer its energy to the water and will cause waves. Ocean waves are one of the factors for coastal changes. Forecasting wave heights using 24-hour wind data in January 2022. The graph of forecasting wave heights on the coast of Topang Island can be seen in Figure 3.

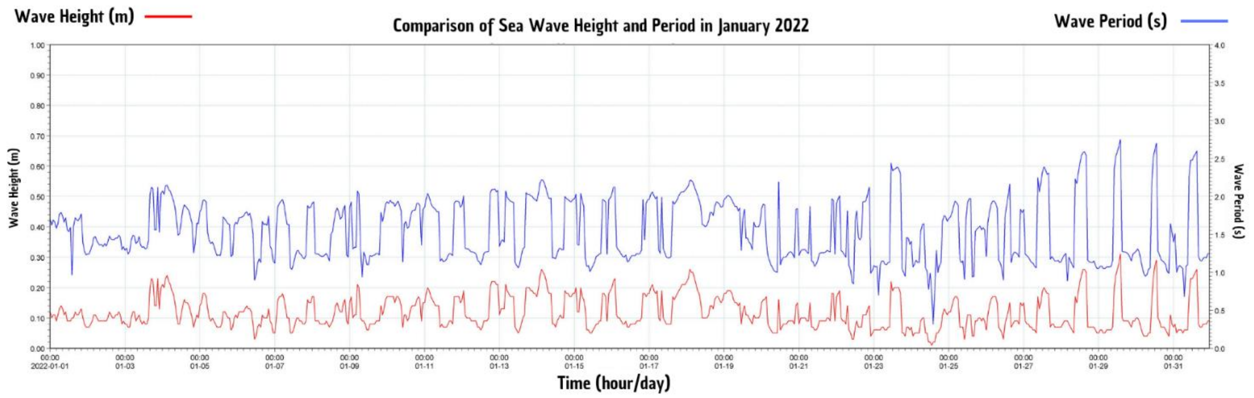


Figure 3. Forecasting Sea Wave Height on the Coast of Topang Island

Based on Figure 3 it is found that the calculation of wave height predictions on the coast of Topang Island is included in the low category because it has an average height of 0.12 meters. In general, the morphology and type of beach is determined by the intensity, frequency and strength of the energy that hits the beach. Areas with low energy, usually sloping, are sedimented with fine sand or mud, while those affected by high energy strength are usually steep, rocky or coarse sand (Soegiarto, 1993; Mahfudz, 2012; Biantara et al., 2016).

The highest wind gusts according to the average wind speed are in the north. The red line is the wave height and the blue line is the wave period. In normal sea waves, the wave height and wave period have a similar pattern. This is related to the height of the waves formed and their duration, so they will have an almost similar pattern. This wave height forecast uses formulas (l) and (m) contained in the methodology. Yuliani et al, (2020) stated that this is indicated by the bigger the wave, the greater the energy received by the shoreline so that the potential for abrasion is greater.

Based on Figure 3 it is found that the calculation of wave height predictions on the coast of Topang Island is included in the low category because it has an average height of 0.12 meters. In general, the morphology and type of beach is determined by the intensity, frequency and strength of the energy that hits the beach. Areas with low energy, usually sloping, are sedimented with fine sand or mud, while those affected by high energy strength are usually steep, rocky or coarse sand (Soegiarto, 1993; Mahfudz, 2012; Biantara et al., 2016).

The highest wind gusts according to the average wind speed are in the north. The red line is the wave height and the blue line is the wave period. In normal sea waves, the wave height and wave period have a similar pattern. This is related to the height of the waves formed and their duration, so they will have an almost similar pattern. This wave height forecast uses formulas (l) and (m) contained in the methodology. Yuliani et al, (2020) stated that this is indicated by the bigger the wave, the greater the energy received by the shoreline so that the potential for abrasion is greater.

BEACH ENVIRONMENTAL CONDITIONS ON TOPANG ISLAND.

The slope of the coast is one of the factors for changing the coastline and observing beach conditions such as the substrate, the presence of mangroves, and community activities around the coast need to be used as supporting data in this study. The results of measuring the slope of the beach and beach conditions on Topang Island can be seen in Table 1.

No	Coordinate point	Observation result	No	Coordinate point	Observation result
1.	Latitude : 0º43’18.934” longitude : 103º6’31.558”	- Lots of fallen mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	7.	Latitude: 0º44’0.791” longitude : 103º5’39.916”	- There are no mangrove trees - Peat soil substrate - There is fishing activity - Abrasion
2.	Latitude: 0º43’32.844” longitude : 103º6’24.606”	- Lots of fallen mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	8.	Latitude: 0º44’38.839” longitude : 103º5’53.686”	- There are many mangrove trees - Mud soil substrate - There is no fishing activity - Akresion
3.	Latitude: 0º44’27.161” longitude : 103º5’33.482” -	- Lots of fallen mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	9.	Latitude: 0º44’28.205” longitude : 103º5’57.109”	- There are many mangrove trees - Mud soil substrate - There is no fishing activity - Akresion
4.	Latitude: 0º43’57.245” longitude : 103º6’12.208”	- There are no mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	10.	Latitude: 0º44’9.337” longitude : 103º6’5.076”	- There are no mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion

5.	Latitude: 0º44'10.237" longitude : 103º5'44.732"	- There are no mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	11.	Latitude: 0º44'27.049" longitude : 103º5'47.353"	- There are no mangrove trees - Peat soil substrate - There is a port - Abrasion
6.	Latitude: 0º44'16.620" longitude : 103º5'52.883"	- There are no mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion	12.	Latitude: 0º44'17.905 longitude : 103º1'57.850	- Lots of fallen mangrove trees - Peat soil substrate - There is no fishing activity - Abrasion

Table 1. The results of measuring the slope of the coast and cones on the beach on Topang Islan

Table 1 is the result of observations in the Topang Island area. The research area is dominated by abrasion. Based on visual observations, Topang Island has peat and muddy beaches. In general, abrasion occurs on soils that tend to have a peat substrate. According to information from farmers on Topang Island, mangrove trees will find it difficult to grow on peat substrate and if they grow they will fall over, then the waves will hit the land directly without any protection and peat soil is easy to carry away so it is prone to abrasion.

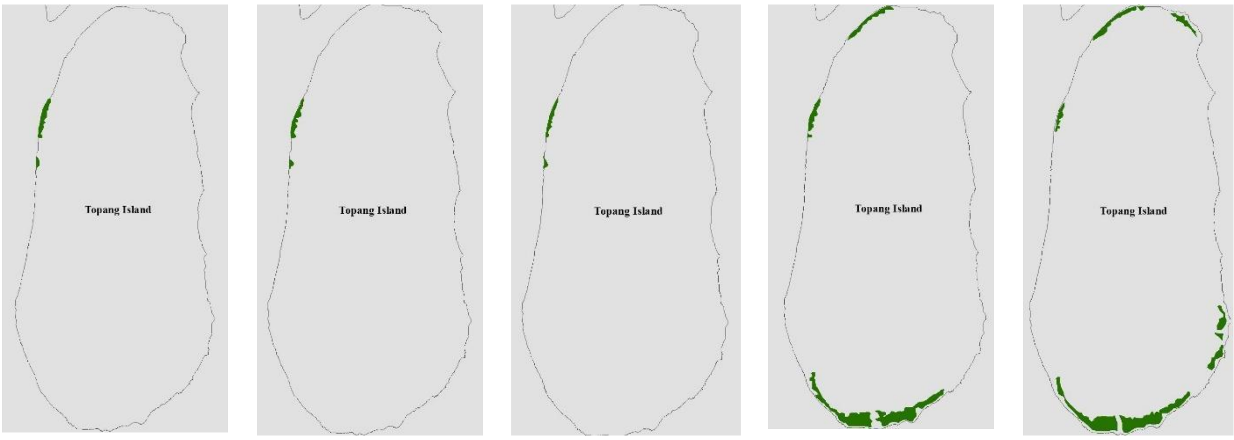
Peatlands in coastal areas have complex problems related to environmental interactions within them, making them very vulnerable to damage (Miloshi & Fairfield, 2015). As happened on Rupat Island, which also has peatlands in its coastal areas, making this area easily damaged by sea waves. One of the most severe peatland abrasions occurred on the North Coast of Bengkalis Island, Riau Province, while the southern coast experienced sedimentation. The abrasion rate that occurs is 59 ha/year and the sedimentation rate that occurs is 16.5 ha/year (Sutikno, 2014).

In several research locations there are also human activities, namely fishermen who dock their boats. According to Handartoputra et al. (2015) human activities such as fishing activities and ferry boat traffic greatly affect environmental conditions and the vulnerability of the surrounding ecosystem, so that it is possible for environmental damage to occur as a result of human activities.

Flat coastal slopes are thought to be related to the condition of the coastal area with wide intertidal areas, as a result of abrasion along the coastal area and the supply of sediment that enters the sea (Kalay et al., 2018).

MANGROVE AREA ON TOPANG ISLAND

Mapping is one of the first steps of a study that can be carried out to observe the condition of mangrove forests which is more effective and efficient in obtaining an overview of the distribution of mangrove forests (Shobirin et al. 2016). The results of the analysis of the mangrove area on Topang Island can be seen in Figure 4.



2001 2006 2011 2016 2021

Figure 4. Results of analysis of mangrove area

Based on Figure 4, it can be seen that mangroves are found on the west side of the island. There was a reduction in mangrove area from 2001 to 2011, then there was an increase in mangrove area in 2016 to 2021. The results of the analysis of the calculation of the mangrove area can be seen in Table 2.

No.	Year	Area (Ha)
1.	2016	106,25
2.	2017	102,14
3.	2018	231,45
4.	2019	165,57
5	2020	119,15
6.	2021	94,82

Table 2. Calculation of mangrove area.

Based on Table 2, the area of mangroves on Topang Island from 2001 to 2021 has seen major changes, be it the addition or reduction of the mangrove area. During the ground check accompanied by the head of the mangrove farmer group on Topang Island, he said that the first time he planted mangrove trees was in 2007 but there was a lack of information on how to care for the mangroves resulting in a failure, in Table 4 there was a decline in the area of mangroves.

The government and local residents replanted in 2012 of course with information on how to care for mangroves even better, can be seen in Table 4 in 2016 the area of mangroves increased and in 2019 replanting was carried out so that in 2021 the area of mangrove forest increased. Mangrove trees can grow optimally on the west side of Topang Island because the substrate is mud and the sea waves are not strong so that planting can be done optimally. Mangroves can grow well on substrates in the form of sand, mud or rock (Masrusoh and Insafitri, 2020). Even though the planting of mangrove seedlings has been carried out, many mangrove trees are still uprooted and washed out to sea, especially in the eastern area of Topang Island, where the substrate is peat and the waves are stronger. Peat material on the surface of the beach is dry, especially during the dry season and when the rainy season arrives, rainfall will increase the mass of peat soil through increasing water content. This will reduce the stability of peat slopes which will cause peat failure (Sutikno et al., 2017).

Research conducted by Dominicis et el (2023) in 2017, experiments on mangroves in Shenzhen Bay have shown that mangroves can locally dampen waves that travel over vegetation towards the shoreline. In an estuary, upstream wave attenuation, that is, cumulative wave reduction over long distances along a restricted estuarine channel, can also reduce extreme water levels in vulnerable upper delta areas, such as in the Guangzhou area.
According to research conducted by Hazazi et al. (2019), the relationship between shoreline changes and mangrove density on the coast of Kendal Regency has a correlation value of 0.5927. These results are reviewed from the level of correlation of research results, including strong correlations.

THE COASTLINE ON TOPANG ISLAND FROM 1991-2021.

Changes in the Topang Island coastline in 1991 – 2021 are shown in Figure 5

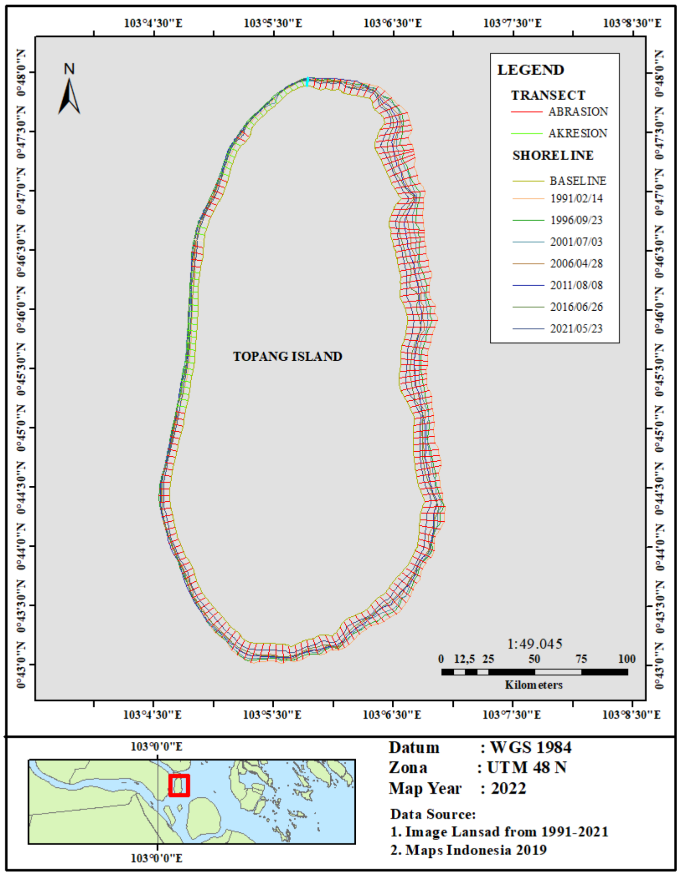


Figure 5. Map of Changes in the Shoreline on Topang Island from 1991 to 2021.

Based on Figure 5, it can be seen that in the period 1991 -2021, changes in the coastline of the coastal area on Topang Island that occurred were dominated by abrasion. To see a graph of the average shoreline change at each transect, see Figure 6.

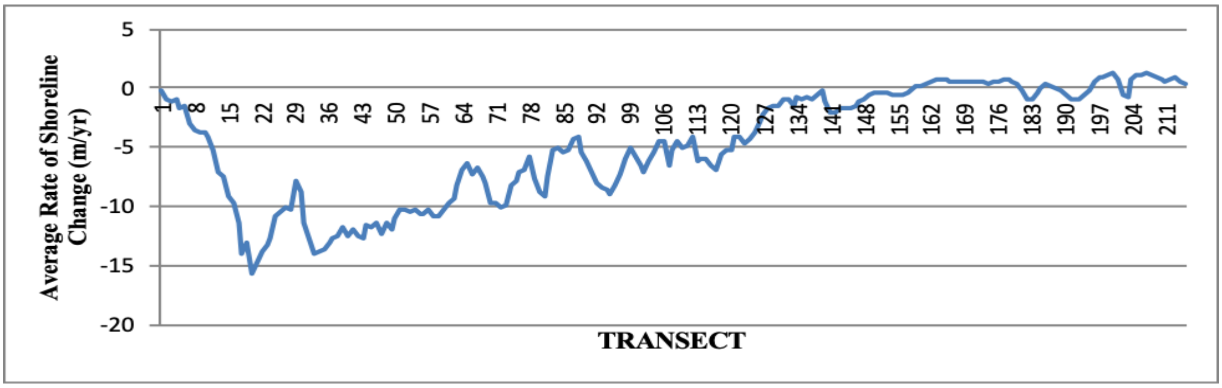


Figure 6. Graph of Shoreline Change

Based on the graph in Figure 6, the vertical numbers explaining the occurrence of abrasion and accretion on the transect are shown in the horizontal numbers. From the graph, it can be seen that abrasion is dominant. The results of calculating the quantitative rate of change in the shoreline of Topang Island can be seen in Table 3.

	Number of Transects	Average Rate of Change (m/yr)	Amount (%)
Abrasion(-)	171	6,13	79,53
Akresion (+)	44	0,62	20,47
Total	215		

Table 3. Result of Calculation of Shoreline Change on Topang Island

Based on Table 3 it can be seen that the results of calculating the average abrasion rate for the coastal area of Topang Island is 6.13 m/year with a total of 171 transects out of 215 total transects and if expressed as a percentage it is 79.53% abrasion.

Total accretion with an average of 0.62 m/year which is divided into 44 transects of the total 215 transects and if expressed as a percentage of 20.47% accretion. Topang Island experiences higher abrasion than Dumai City, the accretion rate for Dumai City is 1.17 m/yr while the abrasion rate is 2.04 m/yr (Mulyadi et al., 2022).

CONCLUSION

The area of the mangrove forest on Topang Island from 2001 to 2011 has decreased, but from 2016 to 2021 it has increased.

Nearly the entire coast of Topang Island has experienced abrasion. The highest abrasion occurs in the east. The eastern part has a peat substrate and receives stronger wave energy than other coastal parts. Accretion occurs in the western part of the island due to the existence of mangrove forests so that the wind is blocked and the waves are not strong.

The change in the coastline on Topang Island from 1991-2021 is 6.13 m/year. Meanwhile, the rate of change of the coastline due to accretion on Topang Island in the 1991-2021 timeframe is 0.62 m/year.

ACKNOWLEDGEMENTS

The author would like to thank Marine Science, University of Riau for facilitating the implementation of this research.

REFERENCES

Biantara B., Hartoko A., y Purwanti F. (2020). Analysis of Coastal Vulnerability and Fishery Resources Using the Sig Approach on the Beaches of Purworejo Regency. Diponegoro Journal of Macquares, 5(2), 1–10.

Bird, E.C.F. (2008). Coastal geomorphology: An introduction (2nd ed.). Wiley, Chichester.

Bosire, J.O., Dahdouh-Guebas, F., Walton, M., Crona, B.I., Lewis III, R.R., Field, C., Cairo, J.G., y Koedam, N. (2008). Functions of restored mangroves: An overview. Aquatic Botany, 89, 251–259.

Dominicis, M.D., Wolf, J., Van Hespen, R., Zheng, P., y Hu, Z. (2015). Mangrove forests can be an effective coastal defense in the Pearl River Delta, China. Earth & Environment, 4(13), 1–13.

Field, C. (1998). Rehabilitation of mangrove ecosystems: An overview. Marine Pollution Bulletin, 37, 383–392.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J., y Duke, N. (2011). Status and distribution of mangrove forests in the world using observational satellite data. *Global Ecology and Biogeography*, 20, 154–159.

Hazazi, G., Sasmito, B., y Firdaus, H.S. (2020). Analysis of shoreline change on mangrove existence using remote sensing data and Digital Shoreline Analysis System (DSAS) application 2014–2018 (Case study: Kendal Regency). *Undip Journal of Geodesy*, 8(1), 19–27.

Jayakumar, J., y Malarvannan, S. (2019). Assessment of shoreline changes in the North Tamil Nadu Coast, South India using WebGIS techniques. *Journal of Coastal Conservation*, 20(6), 477–487.

Kalay, D.E., Lopulissa, F.V., y Noya, Y.A. (2022). Analysis of coastal slope and distribution of beach sediments in Waai State Waters, Salahutu District, Maluku Province. *Triton Journal*, 14(1), 10–18.

Leatherman, S.P., Douglas, B.C., y LaBrecque, J.L. (2003). Sea level and coastal erosion require large-scale monitoring. *EOS Transactions*, 84(2), 13–20.

Marine and Fisheries Ministry. (2021). Coordinating Minister for Maritime Affairs launches Indonesian Maritime Territory Reference Data. Recuperado de https://kkp.go.id/brsdm/poltekkarawang/artikel/14863-menko-maritim-luncurkan-data-rujukan-region-kelautan-indonesia (Accedido el 09 de octubre de 2021).

Mahapatra, M., Ratheesh, R., y Rajawat, A.S. (2014). Analysis of shoreline changes along the South Gujarat Coast, India, using a digital shoreline analysis system. *Journal of the Indian Society of Remote Sensing*, 42(4), 869–876.

Mahfudz, F.D. (2020). *Ecology, benefits & rehabilitation of Indonesian coastal forests*. Manado Forestry Research Institute, Manado, 178 pp.

Miloshi, M., y Fairfield, C.A. (2014). Coastal wetland management: A rating system for potential engineering interventions. *Ecological Engineering*, 75, 195–198.

Muskananfola, M.R., Supriharyono, y Febrianto, S. (2020). Spatio-temporal analysis of shoreline changes along the coast of Sayung Demak, Indonesia using the Digital Coastline Analysis System. *Regional Studies in Marine Science*, 34, 1–9.

Mulyadi, A., Hamidy, R., Musrifin, Efriyeldi, y Jhonnerie, R. (2022). Three decades of the rate of change of the coastline in Dumai City. *Indonesian Environmental Dynamics*, 9(1), 25–31.

Poormima, K.V., Sriganesh, J., y Annadurai, R. (2020). Effect of coastal structures on the North Chennai Coast using remote sensing and GIS techniques. *Journal of Advanced Research in GeoScience and Remote Sensing*, 2(3), 52–60.

Republic of Indonesia. (2018). *Regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 21/PERMEN-KP/2018 concerning Coastal Equivalent Calculations*. Jakarta: Ministry of Maritime Affairs and Fisheries.

Saranathan, E., Chandrasekaran, R., Soosai Manickaraj, D., y Kannan, M. (2019). Shoreline changes in Tharangampadi villages, Nagapattinam District, Tamil Nadu, India: A case study. *Journal of the Indian Society of Remote Sensing*, 39(1), 107–115.

Sutikno, S. (2022). Analysis of Bengkalis Island coastal abrasion rate using satellite data. *Journal of Coastal Studies*, 2(1), 616–625.

Valiela, I., Bowen, J.L., y York, J.K. (2001). Mangroves: One of the world's major threatened tropical environments: At least 35% of mangrove area has been lost in the last two decades, a loss that exceeds the loss of tropical rainforests and reefs. *AIBS Bulletin*, 51, 807–815.

Wang, L., Jia, M., Yina, D., y Tian, J. (2019). A review of remote sensing for mangrove forests: 1956–2018. *Remote Sensing of Environment*, 231, 1–27.

Yuliani, A.D., y Rejeki, H.A. (2022). The influence of waves on abrasion in the coastal districts of Demak, Kendal, and Semarang City. *Indonesian Journal of Oceanography*, 2(4), 1–8.