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published in MORSKOY GIDROFIZICHESKIY ZHURNAL, Vol. 38, Iss. 5 (2022)

Evolution of the Coastline in Padang Pariaman Regency, West Sumatra, Indonesia: Analysis Period from 1988 to 2018

W. Prarikeslan ✉, N. Syah, Y. Nanda

Universitas Negeri Padang, Padang, West Sumatra, Indonesia
✉ widya_geo@fis.unp.ac.id

Abstract
Purpose. The study is aimed to analyze the evolution of the coastline of Padang Pariaman Regency, as well as some oceanographic and anthropogenic factors.
Methods and Results. In this paper, the results of survey studies are quantified. The coastline evolution is observed using remote sensing techniques on Landsat image data collection and Geographic Information System (GIS) techniques. The coastline evolution is estimated using the overlay method. The evolution of the coastline of Padang Pariaman Regency is due to abrasion along the coast, especially in Katapiang village covering an area of 49.76 ha, where an increase of 27.63 ha from the previous period can be observed. The largest accretion occurred in the village of Malai V Suku with an additional 12.30 ha of land and the Pilubang village with an additional 4.84 ha of land. Such hydro-oceanographic factors as wave speed, high current velocity, and tides affect coastal abrasion in the Padang Pariaman District.
Conclusions. The evolution of the coastline is influenced by oceanographic and anthropogenic factors. An oceanographic factor in the form of the highest tide can be observed in Ulakan and Tapakis villages. Anthropogenic factors and the largest land changes can be found in the village of Malai V Suku, amounting to 29.21 ha, and in Katapiang village with an increase of 27.63 ha from the previous period.

Keywords: coastline evolution, abrasion, accretion, Padang Pariaman, remote sensor, GIS

Acknowledgments: The authors thank the Heads of Research and Community Service Institutions and the Chancellor of Universitas Negeri Padang, Padang, West Sumatra, Indonesia who have funded this research under the following contract No: 023.17.2.677514/2021

For citation: Prarikeslan, W., Syah, N. and Nanda, Y., 2022. Evolution of the Coastline in Padang Pariaman Regency, West Sumatra, Indonesia: Analysis Period from 1988 to 2018. *Physical Oceanography*, 29(5), pp. 536-547. doi:10.22449/1573-160X-2022-5-536-547

DOI: 10.22449/1573-160X-2022-5-536-547

Introduction

The coastline is the meeting point between land and sea, which helps to achieve a natural balance. The dynamic nature of a beach is a natural response of the coast to the environmental conditions surrounding it. The environment around the coast is used by people for various activities, such as tourism, housing, fishing, agriculture, and industry. The research results [1] state that the resident population inhabits almost 45% of coastal areas, and that puts constant pressure on the evolution of coastlines. In addition, the influence of natural factors, such as sediments, sea currents, sea surface wave movements, and sea level, also affects the coastline, which has increased from 0.26 m to 0.55 m [2]. Rising sea levels affect waves, floods, and storms, and increase sociol-economic and ecological risks to communities around coastlines.

The evolution of the coastline is followed by a change in its position, which is caused by several factors and interactions between factors, namely nature, and people. Natural factors are derived from hydro-oceanographic processes, such as wave and current speed, tidal variation, and climate change. The results of the research by [3] state that anthropogenic factors, such as housing development and tourism in coastal areas affect the evolution of shorelines. This disrupts the balance of sediment transport along the coast. In addition, sand mining causes changes in current and wave patterns [4]. Therefore, abrasion and accretion can be observed on almost all coasts in Indonesia, for instance, in Bengkulu Residency, Demak Residency, Teluk Awur in Jepara Residency, Cisadane waters in Banten Province, Soropia Sub-Residency in Southeast Sulawesi, Makassar in South Sulawesi, and Padang Pariaman Regency in West Sumatra [5–10].

The coastal position of Padang Pariaman Regency is flat because it is on a slope of < 20%. At a distance from 0 m to 5000 m towards the sea, the seawater depth is 20 m. At a distance of 20 km toward the sea, the depth of seawater is from 0 m to 125 m. Ocean currents move from the north towards the north and the south coasts of Padang Pariaman Regency [10]. The coastline evolution of Padang Pariaman Regency is related to the waves of the Indian Ocean. This causes the coastline of Padang Pariaman Regency to be vulnerable to abrasion and accretion.

Changes in wind direction that occur in Padang Pariaman Regency also result in the same phenomena. In addition, two handrails installed along the shoreline of Padang Pariaman Regency are now located in the middle of the sea because the beach sand has been crushed by waves of about 30 meters. The distance from the beach to the houses of residents, which is 6 m, is even closer now because the waves hitting the coast of Padang Pariaman Regency are very strong. The government of Padang Pariaman Regency has not yet made regulations on handling and preserving coastal ecosystems.

Several researchers have found various solutions to the problems that occur on the coast of Padang Pariaman Regency. The characteristics of the coast and the abrasion process in Padang Pariaman District were described in [11], the coastal vulnerability was investigated with Analytic Hierarchy Process (AHP) in [12], and the coastline was studied by looking at natural factors and sediments in the estuary in [13], while [14–15] studied only coastal vegetation. Some limitations could be observed in the abovementioned research, for example, [11] examined the abrasion process only from the hydro-oceanographic factor, [13] researched only in the estuary, while [14–15] examined coastal plant types.

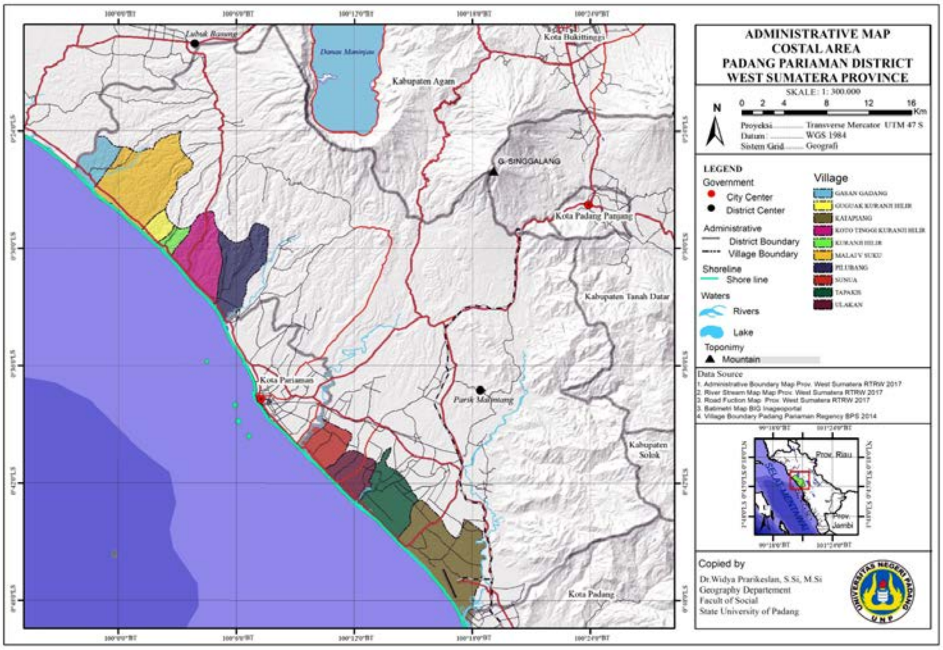
The results of the studies above show that the research conducted is not comprehensive. Therefore, it is necessary to conduct research that examines all aspects of the causes of accretion and abrasion that occur on the coast of Padang Pariaman Regency. This study is aimed to analyze the coastline evolution of Padang Pariaman Regency, as well as hydro-oceanographic and anthropogenic factors. Hydro-oceanographic factors are natural factors that can change the beach area, such as waves, currents, and tides. Anthropogenic factors are factors of continuous human activity that cause shoreline changes. Both of these factors can occur and change according to variations in parameters and environmental conditions.

Area of work, materials, and methods

The geomorphology of the coast of Padang Pariaman Regency is as follows: lowlands (40%) in the form of Fluvial Plain units with concave slopes, oxygen morphogenesis (river flows), 0–2% slopes; and land use in this area is dominated by settlement and agriculture.

The coast of Padang Pariaman Regency consists of alluvium deposits (silt, sand, and gravel), which are widespread almost all over. In the north, though, their distribution is a bit narrow because there are pumice tuff terraces from the latest eruption of Maninjau Caldera and basaltic andesite originating from a Pleistocene volcano.

Field survey activities were carried out to examine the condition of the coastline at 10 points or villages in Padang Pariaman District: Gasan Gadang, Guguak Kuranji Hilir, Katapiang, Koto Tinggi Kuranji Hilir, Kuranji Hilir, Malai V Suku, Pilubang, Sunua, Tapakis, and Ulakan (Figure).



F i g u r e. Map of the coastal area of Padang Pariaman Regency

The sources of the map shown in the Figure are the Map of West Sumatra Province Administrative Boundary RTRW 2017, the River Flow Map of West Sumatra Province RTRW 2017, the Road Function Map of West Sumatra Province RTRW 2017, and the Village Boundary Map of Padang Pariaman Regency.

The materials used in this study were Landsat 8 imagery in 2018, Landsat 5 imagery in 2003, Landsat 5 imagery in 1988, and DEM data. The tools implemented were the Asus Core i5 laptop, ArcGIS 10.5, ENVI 5.1, and Global Mapper 17 software. This research used a quantitative survey method, and observations of shoreline changes were carried out with the help of remote sensing techniques on Landsat image data sets and Geographic Information System (GIS) techniques. Shoreline changes were observed using the overlay method, which can determine shoreline shifts, such as abrasion and accretion. The data sources were obtained from satellite images (Espa.cr.usgs.gov), wave speed (www.ecmwf.int), current speed (www.aviso.altimetry.fr), and tide (Naotide).

The data analysis technique in this study uses 3 parameters, namely:

1. Coastline evolution

The indicators used to determine the evolution of the coastline are abrasion and accretion obtained from multiple map overlays and calculated statistics.

2. Hydro-oceanographic factors

The indicators used to estimate hydro-oceanographic factors are waves (naotide), tides (www.ecmwf.int), and currents (www.aviso.altimetry.fr).

3. Anthropogenic factors

The indicators used to evaluate anthropogenic factors are area change (Landsat 5 TM 1988, 2003) and beach vegetation (Lands 8 OLI 2018).

The magnitude of the longshore current can be found by calculating the high value of the breaking wave [16–18].

The breaking wave height (*H*) can be determined as follows:

$$the\ \frac{Hb}{Ho'} = 0.56 \cdot \left(\frac{Ho'}{Lo}\right)^{-\frac{1}{5}},$$

where *Hb* is breaking wave height (m); *Ho*' is sea wave height in equivalent (m) and *Lo* is wavelength in the deep sea (m).

The depth of the breaking wave (*db*) can be calculated using the following formula:

$$db = Hb/(gT^2)$$

where *Hb* is breaking wave height (m); *g* is the acceleration due to gravity (m/s^2) and *T* is wave period (s).

Breaking wavelength (*Lb*) can be found using:

$$Lb = T\sqrt{g(db)}$$

where *T* is wave period (s); *g* is the acceleration due to gravity (m/s^2); *db* is the depth of breaking waves (m).

The breaking wavelength *Lb* (a_b) can be found as follows:

$$\frac{\sin a_b}{Lb} = \frac{\sin a_o}{Lo},$$

where a_b is an angle of incidence of breaking waves (°); *Lb* is breaking wavelength (m); a_o is an angle between the crest of the wave in the deep sea and the shoreline (°); *Lo* is wavelength in deep sea (m).

The current speed along the coast (*V*) can be found using:

$$V = 1.17\,(g \cdot Hb)^{\frac{1}{2}} \sin a_b \cos a_b$$

where *g* is the acceleration due to gravity (m/s^2); *Hb* is breaking wave height (m); a_b is an angle of incidence of breaking waves (°).

The wave data is downloaded on the ECMWF website. The downloaded data is provided in the form of wave period data (*T*), and deep-sea wave height (*Ho'*), which has a netchdf (ns) format. The data is also downloaded at the coordinates of the Padang City area with a grid of 0.125° × 0.125°. Both data are then converted using

Ocean Data View software. The processed data are daily data, which are then averaged with the help of Mircosoft Excel software.

Analysis of the results

The coastline of Padang Pariaman Regency is 60.5 km and it is prone to abrasion and accretion because of its location directly opposite of the Indian Ocean. The activity of waves, currents, and tides causes the loss of coastal land. This condition is referred to as abrasion [19, 20], and it leads to the shrinkage of the beach width and the evolution of the coastline.

Coastline evolution analysis

Abrasion and accretion are the dominant factors causing coastline evolution. Abrasion can occur due to the influence of nature and many human activities along the coast. For example, sediment can be eroded from the coast due to an unbalanced sediment movement. Changing global climate is also responsible for sediment movement because climate change influences wind speed, and the wind is a factor that affects wave size. In the period from 1988 to 2018, the coastline evolution of Padang Pariaman Regency was caused by abrasion and accretion (Table 1).

Table 1

Abrasion and accretion data for the coast of Padang Pariaman Regency (1988–2018)

Village names	Abrasion, ha			Accretion, ha		
	1998–2003	2003–2018	1988–2018	1988–2003	2003–2018	1988–2018
Gasan Gadang	2.52	13.75	10.99	4.23	0.50	0.18
Malai V Suku	4.73	15.58	17.84	3.29	12.30	12.25
Guguak Kuranji Hilir	8.91	13.55	20.17	1.09	2.49	1.23
Kuranji Hilir	6.96	11.38	15.98	1.70	0.01	1.25
Koto Tinggi Kuranji Hilir	16.76	8.26	23.65	2.51	1.36	17.67
Pilubang	18.85	–	25.21	3.42	4.84	2.78
Sunua	9.70	9.01	16.64	2.96	0.44	1.30
Ulakan	18.25	14.50	22.78	–	3.05	–
Tapakis	18.27	16.45	33.35	0.70	0.97	0.25
Katapiang	22.13	49.76	58.18	6.59	0.21	1.04

In the period from 2003 to 2018, an abrasion of 49.76 ha in Katapiang village damaged many people’s houses. According to [21] the average coastal abrasion in Padang Pariaman Regency amounted to 17.61 ha, and occurred in 5 villages. It is related to the fact that the coast of Padang Pariaman Regency is directly connected to the Indian Ocean and there are no coastal protection structures. In addition, coastal abrasion occurs because the sediment is in the soft form, so it is easily carried by wave currents to other places. The high rate of coastal erosion at several locations in Padang Pariaman District over the last 5 years caused abrasion according to [22]. Besides, coastal abrasion can occur when the sediment movement to another place is greater than the sediment movement to the beach [21].

The waves that come and hit the beach contribute to the movement of sediment along the coast. Repeated wave motions in a zigzag pattern carry sediments to other places. Abrasion can occur due to the loss of coral reefs and mangrove plants on the coastline, as they play a role in resisting erosion and moving the sediment to other places.

In the period from 2003 to 2018, some accretion occurred along the coast of Padang Pariaman Regency. The area of the shoreline/land increased towards the Indian Ocean. The largest accretion took place in the village of Malai V Suku with an additional 12.30 ha of land and Pilubang village with an additional 4.84 ha. It happened due to the movement of large sediments from rivers, which were carried by ocean currents. Sediment deposits are concentrated in deltaic areas, areas rich in coral reefs, and areas with high vegetation. Coral reefs and vegetation roots that grow on the coast inhibit the movement of sediment to other places, so that sediment accumulates and forms new land.

Hydro-oceanographic factor analysis

The hydro-oceanographic factors, such as wave speed, high current velocity, and tides affect coastal abrasion in Padang Pariaman District. Based on the results of the R studio statistical test that has been carried out with panel data regression analysis, it is found that the appropriate estimate is the random effect test of 3 hydro-oceanographic factors. In Table 2, statistical calculation using the panel data regression method shows the influence of hydro-oceanographic factors on changes in the beach area. The value of 0.0011 indicates that changes in the beach area are influenced by hydro-oceanographic factors because the value obtained is smaller than the alpha value of 0.05, meaning that the alpha value is 0.05, and the power of influence is 40%. The p-value is 0.0029, which means that the null hypothesis is rejected so that the coastline is simultaneously affected by the independent variable. Current velocity and wave speed do not affect the occurrence of abrasion.

Based on the data in Table 2 (1988, 2003, 2018), the main cause of abrasion on the coast of Padang Pariaman Regency is shown. In 2018 the highest tides were in the villages of Malai V Suku and Guguak Kuranji Hilir, while the lowest occurred in Gasan Gadang village. Abrasion in the northern part of the coast of Padang Pariaman Regency is smaller than in the southern part because the geology of the composition is different. This is caused by pumice tuff terraces from the latest eruption of Maninjau Caldera and basal andesite originating from the Pleistocene and Holocene volcanoes. Tides are regular rising and falling sea level movements [23]. Tides and sea levels play a role in coastal processes such as the spread of sediment and coastal abrasion. High tide spreads sediment near the coast, while low tide causes the sedimentation process to advance toward the open sea. Tidal currents are generally not so strong as to transport large sediments.

T a b l e 2

Hydro-oceanographic factors affecting abrasion (1988–2018)

Village names	Wave speed, m/s			Current speed, m/s			Tide, m		
	1988	2003	2018	1988	2003	2018	1988	2003	2018
Gasan Gadang	7.19	10.8	7.43	1.11	1.20	1.85	1.19	1.35	2.18
Malai V Suku	6.37	9.57	6.57	0.98	1.17	1.80	1.18	1.35	2.28
Guguak Kuranji Hilir	7.26	10.91	7.49	1.12	0.77	1.18	1.18	1.34	2.27
Kuranji Hilir	5.34	8.02	5.52	0.83	0.82	1.26	1.17	1.34	2.26
Koto Tinggi Kuranji Hilir	7.72	11.6	7.97	1.18	0.82	1.27	1.17	1.33	2.25
Pilubang	4.66	7.00	4.81	0.72	0.95	1.48	1.16	1.33	2.24
Sunua	5.64	8.47	5.83	0.87	0.70	1.09	1.13	1.30	2.20
Ulakan	6.41	8.48	6.62	0.99	0.74	1.15	1.12	1.29	2.19
Tapakis	6.95	10.44	7.17	1.07	1.04	1.62	1.12	1.29	2.19
Katapiang	5.65	8.48	5.83	0.88	0.64	0.99	1.11	1.27	2.16

Wind and atmospheric pressure on the water's surface affect the water level. The force of the wind pushes the water surface towards the land causing the water level to rise. The influence of weather varies in water levels; these phenomena are known as storms and barometric waves. Hurricanes and barometric waves can lead to coastal damage and flooding [24]. Hurricanes occur due to wind pressure at sea level and reduced atmospheric pressure, while barometric waves take place due to storm surges. Barometric waves are generated by an imbalance between the sea level and barometric pressure, the surface water rises as atmospheric pressure decreases by about 0.1 m for each kPa of difference in pressure [20].

Astronomically, tides occur because of the regular rise and fall of sea levels. On the other hand, the rise and fall of sea levels depend on the tides. This is caused by the gravitational interaction between the moon and the sun. This interaction affects the tides in several different places. The height of the ocean waves in deep waters is generally < 0.5 m in shallow waters modified by shoaling and friction; in certain places, sea waves can reach a height of > 15 m. Tidal conditions in a particular place are different and are governed by the constituents of semi-diurnal and diurnal tides. The semi-diurnal constituent causes 2 high and 2 low tides every day, while the diurnal tidal constituent causes 1 high and 1 low tide every day. In addition, tides can occur on the full moon and on the new moon [9].

The amount of force affected by the gravitational interaction of the earth, sun, and moon results in periodic variations in the large mass of water. Due to these forces, the rise and fall of water masses are called astronomical tides, while the resulting horizontal motions are called tidal currents. The most important tidal component is caused by the pull of the moon with a maximum value of 12-hour and 25-minute intervals. As a result, the maximum and minimum fluctuations in the mean sea level are delayed by 50 minutes per day, corresponding to a lunar day lasting 24 hours and 50 minutes. The second component of the tide is affected by the sun’s gravitational pull, with a period of 12 hours, which in turn enhances or dampens the semi-diurnal effect of the moon. When the two attractive forces affected by the sun and moon are in conjunction or opposite in phase, the tides at a location show a maximum level and are called spring tides; when the two forces differ in phase by a quarter (the moon in the first or in the third half) the tide assumes a minimum value and is called a new tide [20].

The theory of tidal balance explains that the tides are known through the suitability and influence of the gravitational force, so that each planet is always in its orbit around the sun and the moon – around the earth. The balance theory states that tides are not regulated by the seabed. The sea produces forces that shape the position of its surface. The sea surface adjusts to the various forces that interact with it. The tides vary depending on the configuration of the basin. The tides on the lake are lower than on the sea. Tidal variations differ from the coast to the center of the ocean. The highest tides occur at the edges of the largest ocean basins, such as bays. Extreme tides can be encountered in some locations caused by natural oscillation periods of about 12 or 24 hours. The speed of an open ocean tidal current can be measured in cm/s, and it will decrease according to the ocean depth. Beaches experience abrasion quickly if the waves hit one place for a long time. In order to experience abrasion slowly, they need to be protected by offshore islands [21].

Anthropogenic factor analysis

Anthropogenic factors are geomorphological processes caused by human activities on the coast that can destabilize the coastal environment. Anthropogenic factors affect the physical environment and the lives of people who live and work in coastal areas. The results of statistical tests carried out show that anthropogenic factors in the form of land changes influence accretion on the coastline of Padang Pariaman Regency with a value of 0.04, which is below the alpha value of 0.05 with an R-squared value of 18%. The anthropogenic factors include land changes that bring about changes in coastal vegetation in Padang Pariaman Regency (Table 3).

The data in Table 3 shows that from 1988 to 2018 there was a change of 29.21 ha in the coastal vegetation area of the village of Malai V Suku. The village was used for anthropogenic activities, such as making shrimp ponds, and it was causing changes in the coastal vegetation area. Besides, a sea reclamation project was adopted there that moved the land and the coastline of the village towards the sea. This brought hydrodynamic changes and affected the topography and dynamics of sediment erosion of the coastline of Padang Pariaman Regency. As a result, a change in the coastal vegetation of the Padang Pariaman Regency was noted. In the northern part of Padang Pariaman beach (Gadang Gadang village), an increase in the vegetation area was noted, while in the southern part of Padang Pariaman beach (Katapiang village) a reduction in the vegetation area was observed. In addition, this beach is an area bordering the river mouth [25]. Land materials enter the river waters, go to the sea and then settle at the bottom of the waters to form sediments and spread to the coast [26].

T a b l e 3

Changes in coastal vegetation area (1998–2018)

Village names	Vegetated land areas, ha			Land change, ha		
	1988	2003	2018	1988–2003	2003–2018	1988–2018
Gasan Gadang	0.00	1.65	8.32	1.65	6.67	8.32
Malai V Suku	30.70	47.58	59.91	16.88	12.33	29.21
Guguak Kuranji Hilir	12.20	16.10	22.26	3.90	6.16	10.06
Kuranji Hilir	10.90	12.47	19.39	1.57	6.92	8.49
Koto Tinggi Kuranji Hilir	27.14	39.86	47.20	12.72	7.34	20.06
Pilubang	5.31	3.75	4.06	−1.56	0.31	−1.25
Sunua	14.56	12.81	15.78	−1.75	2.97	1.22
Ulakan	46.02	43.35	39.71	−2.67	−3.64	−6.31
Tapakis	23.84	30.07	21.33	6.23	−8.74	−2.51
Katapiang	77.86	57.41	64.30	−20.45	6.89	−13.56

The coastal environment is an area that always changes. The changes in the coastal environment can occur both slowly and rapidly. It all depends on the balance of forces between topographic, rock, wave, tidal, and wind characteristics. Changes in the coastline can have a positive impact (increase in land area) and a negative impact (erosion of some land resulting in a decline of the coastline). Both of these impacts can occur and always change according to shifts in parameters and environmental conditions. The accumulation of deposited material, in a certain period, affects the area and the land in coastal areas [27]. Anthropogenic factors consist of land clearing upstream of rivers and clearing of mangroves. Sediment accumulation occurs in areas with a lot of anthropogenic activity [28].

The condition of the coastal environment deteriorates if the coast is not used properly and the situation is not controlled. The increasing number of people using uncontrolled coastal areas and exploiting coastal areas to the extreme leads to coastal erosion, pollution, shoreline evolution, sedimentation, and silting of bays [29]. The clearing of mangrove forests in areas that have a high level of tourism and aquaculture activities has an environmental impact on the coastal ecosystem. Places that have residential areas endanger both the population and the physical condition of the beach. The more settlements there are around the coast, the greater the risk, including coastal damage due to land conversion and human activities [30].

Conclusion

The coastline evolution of Padang Pariaman Regency, West Sumatra, Indonesia occurred due to coast abrasion and amounted to 49.76 ha, especially in Katapiang village. It is an increase from the previous period when the coastline evolution in this region amounted to 27.63 ha. This phenomenon was influenced by hydro-oceanographic and anthropogenic factors. The hydro-oceanographic factors in the form of the highest tides were observed in Ulakan and Tapakis villages. The anthropogenic factors in the form of the largest land change of 29.21 ha occurred in the village of Malai V Suku.

REFERENCES

1. Mentaschi, L., Vousdoukas, M.I., Pekel, J.-F., Voukouvalas, E. and Feyen, L., 2018. Global Long-Term Observations of Coastal Erosion and Accretion. *Scientific Reports*, 8, 12876. doi:10.1038/s41598-018-30904-w
2. Santos, C.A.G., Nascimento, T.V.M.D., Mishra, M. and da Silva, R.M., 2021. Analysis of Long- and Short-Term Shoreline Change Dynamics: A Study Case of João Pessoa City in Brazil. *Science of The Total Environment*, 769, 144889. doi:10.1016/j.scitotenv.2020.144889
3. Prasad, D.H. and Kumar, N.D., 2014. Coastal Erosion Studies – A Review. *International Journal of Geosciences*, 5(3), pp. 341-345. doi:10.4236/IJG.2014.53033
4. Bini, M. and Rossi, V., 2021. Climate Change and Anthropogenic Impact on Coastal Environments. *Water*, 13(9), 1182. doi:10.3390/w13091182
5. Tarigan, M.S., 2007. Observation and Change Analysis of Coastline in the Cisadane Coast, Banten Province. *Makara Journal of Science*, 11(1), pp. 49-55. doi:10.7454/mss.v11i1.242 (in Bahasa).
6. Ramadhani, Y.P., Praktikto, I. and Suryono, C.A., 2021. Changes in Coastlines Using Landsat Satellite Imagery on the Coast of Sayung District, Demak Regency. *Journal of Marine Research*, 10(2), pp. 299-305. doi:10.14710/jmr.v10i2.30468 (in Bahasa).
7. Putra, I.M.A.W., Susanto, A. and Soesanti, I., 2015. Pemodelan Perubahan Garis Pantai Dengan Metode End Point Rate Pada Citra Satelit Landsat [Coastline Change Modeling Using Endpoint Rate Method on Landsat Satellite Imagery]. *Semnasteknomedia Online*, 3(1), pp. 19-24 (in Bahasa).
8. Maulana, F.A., Amri, K. and Besperi, 2021. Prediction of Changes in Bengkulu Beach Line (Case Study Zakat Beach City of Bengkulu City). *Radial: Jurnal Peradaban Sains, Rekayasa dan Teknologi*, 9(1), pp. 15-22. doi:10.37971/radial.v9i1.216 (in Bahasa).
9. Siregar, N.P., Subardjo, P. and Setiyono, H., 2014. Studi Perubahan Garis Pantai Di Perairan Keling Kabupaten Jepara [Study of Shoreline Changes in Keling Waters, Jepara Regency]. *Journal of Oceanography*, 3(3), pp. 317-327 (in Bahasa).
10. Ondara, K., Rahmawan, G.A. and Pitri, Y.A., 2018. Kerentanan Pesisir Kota Pariaman, Sumatera Barat Menggunakan Pemodelan Numerik Hidro-Oseanografi [Coastal Vulnerability of Pariaman City, West Sumatra Using Hydro-Oceanographic Numerical Modeling]. In: W. A. Nugraha, A. Romadhon, Insafitri, eds., 2019. *Prosiding Seminar Nasional Kelautan dan Perikanan IV 2018 Swiss-Belinn, Tunjungan-Surabaya 05 September 2018* [4th Proceedings of the National Seminar on Marine and Fisheries. Swiss-Belinn, Tunjungan-Surabaya 05 September 2018]. Pertama, pp. 13-24 (in Bahasa).
11. Solihuddin, T., 2011. Coastal Characteristic and Erosion Processes at Padang Pariaman Coast, West Sumatra. *Globe*, 13(2), pp. 112-120 (in Bahasa).
12. Bagdanavičiūtė, I., Kelpšaitė, L. and Soomere, T., 2015. Multi-Criteria Evaluation Approach to Coastal Vulnerability Index Development in Micro-Tidal Low-Lying Areas. *Ocean & Coastal Management*, 104, pp. 124-135. doi:10.1016/j.ocecoaman.2014.12.011
13. Xu, X., Li, X., Chen, M., Li, X., Duan, X., Zhu, G., Feng, Z. and Ma, Z., 2016. Land-Ocean-Human Interactions in Intensively Developing Coastal Zone: Demonstration of Case Studies. *Ocean & Coastal Management*, 133, pp. 28-36. doi:10.1016/j.ocecoaman.2016.09.006
14. Samin, A.N., Chairul and Mukhtar, E., 2016. Analisis Vegetasi Tumbuhan Pantai Pada Kawasan Wisata Pasir Jambak, Kota Padang [Analysis of Coastal Vegetation in the Pasir Jambak Tourist Area, Padang City]. *Biocelebes*, 10(2), pp. 32-42 (in Bahasa).

15. Araujo, D.S.D. and Pereira, M.C.A., 2016. Sandy Coastal Vegetation. In: K. Del Claro, P. S. Oliveira, V. Rico-Gray, eds., 2016. *Tropical Biology and Conservation Management.* Brazil: Encyclopedia of Life Support Systems. Vol. 4: Tropical Botany, pp. 173-189. Available at: https://www.eolss.net/ebooklib/tropical-biology-conservation-management.aspx [Accessed: 08 June 2022].

16. Tiro, M.A., 2019. *Analisis Korelasi dan Regresi* [Correlation and Regression Analysis]. Makassar, Indonesia: Andira Publisher, 117 p. (in Bahasa).

17. Komar, P.D. and Oltman-Shay, J., 1989. The Continuity Equation for Longshore Current Velocity with Breaker Angle Adjusted for a Wave-Current Interaction, by Cyril Galvin. *Coastal Engineering*, 13(4), pp. 379-385. doi:10.1016/0378-3839(89)90043-4

18. Atmojo, H.T., Rizal, A., Nauval, F., Sadewo, D.W., Hanenda, A., Nugroho, H., Kurniasih, A. and Cibaj, I., 2016. Longshore Bar Deposits in a Modern Fluvial-Dominated Delta: A Case Study from the Wulan Delta, Demak, Central Java, Indonesia. *Berita Sedimentologi*, 36(1), pp. 44-65 (in Bahasa).

19. Irawan, S., Fahmi, R. and Roziqin, A., 2018. Hydro-Oceanographic Condition (Tides, Currents and Waves) of Nongsa Batam Waters. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, 11(1), pp. 56-68. doi:10.21107/jk.v11i1.4496 (in Bahasa).

20. Hakim, F.L., Osawa, T. and Sandi Adnyana, I.W., 2021. Shoreline Change Analysis Using Digital Shoreline Analysis System Method in Southeast Bali Island. *Journal of Environmental Science*, 15(1), pp. 61-74. doi:10.24843/EJES.2021.v15.i01.p06

21. Haryani, H., Irianto, A. and Syah, N., 2019. Kajian Perubahan Garis Pantai Provinsi Sumatera Barat Periode 2003 – 2016. *Tataloka*, 21(2), pp. 293-304. doi:10.14710/tataloka.21.2.293-304 (in Bahasa).

22. Fauzi, Mubarak, M. and Elizal, E., 2020. Coastal Vulnerability Analysis in Padang Pariaman Regency, West Sumatera. *Asian Journal of Aquatic Sciences*, 3(1), pp. 69-76. doi:10.31258/ajoas.3.1.69-76

23. Prarikeslan, W., 2016. *Oseanografi* [Oceanography]. Jakarta, Indonesia: Predana Media Kencana, 145 p. (in Bahasa).

24. Oktorie, O., Barlian, E., Putra, A., and Ramadhan, R., 2019. Disaster Mitigation Based on Environmental of Coastal Area Communities in Pariaman City Indonesia. *Sumatra Journal of Disaster, Geography and Geography Education*, 3(2), pp. 202-207.

25. Putri, E.E., Galib, M. and Mubarak, M., 2021. Analysis of Inundation Area as an Impact of Sea Level Rise in Kota Pariaman District, West Sumatera Province. *Journal of Coastal and Ocean Sciences*, 2(3), pp. 193-200. doi:10.31258/jocos.2.3.193-200

26. Dimyati, M., Trihatmoko, E. and Marfai, M.A., 2021. 10 Years Erosion-Sedimentation Monitoring: System Based Automatic Interpretation in Coastal Area of Brebes Regency, Central Java Province, Indonesia. *Geographia Technica*, 16(1), pp. 25-38. doi:10.21163/GT_2021.161.03

27. Siswanto, E., Tang, J., Yamaguchi, H., Ahn, Y.-H., Ishizaka, J., Yoo, S., Kim, S.-W., Kiyomoto, Y., Yamada, K., Chiang, C. and Kawamura, H., 2011. Empirical Ocean-Color Algorithms to Retrieve Chlorophyll-a, Total Suspended Matter, and Colored Dissolved Organic Matter Absorption Coefficient in the Yellow and East China Seas. *Journal of Oceanography*, 67(5), pp. 627-650. doi:10.1007/s10872-011-0062-z

28. Kotelyanets, E.A., Gurov, K.I., Tikhonova, E.A. and Kondratev, S.I., 2019. Pollutants in Bottom Sediments in the Balaklava Bay (the Black Sea). *Physical Oceanography*, 26(5), pp. 414-424. doi:10.22449/1573-160X-2019-5-414-424

29. Brigante, R. and Radicioni, F., 2014. Use of Multispectral Sensors with High Spatial Resolution for Territorial and Environmental Analysis. *Geographia Technica*, 9(2), pp. 9-20.

30. Kakisina, T.J., Anggoro, S., Hartoko, A. and Suripin, 2015. Analysis of the Impact of Land Use on the Degradation of Coastal Areas at Ambon Bay-Moluccas Province Indonesia. *Procedia Environmental Sciences*, 23, pp. 266-273. doi:10.1016/j.proenv.2015.01.040

About the authors:

Widya Prarikeslan, Lecturer and Researcher, Geography Department, Universitas Negeri Padang, Padang, West Sumatra, Indonesia, Ph.D. (Oceanography), **ORCID ID**: **0000-0002-2974-8472**, **Scopus Author ID: 57209394362**, widya_geo@fis.unp.ac.id

Nurhasan Syah, Lecturer and Researcher, Environmental Sciences Department, Universitas Negeri Padang, Padang, West Sumatra, Indonesia, Ph.D. (Environmental Science), **ORCID ID: 0000-0003-0264-5884**, **Scopus Author ID: 57200419486**, nurhasan_s@yahoo.com

Yulia Nanda, Researcher Geography Department, Faculty of Social Science, Universitas Negeri Padang, Padang, West Sumatra, Indonesia, B.S. (Geography), yulia.nanda7696@gmail.com

Contribution of the co-authors:

Widya Prarikeslan – participated in field studies, prepared graphic material and wrote the main text of the paper

Nurhasan Syah – participated in setting the goals and objectives, developed approaches to the analysis, analysed the necessary data

Yulia Nanda – participated in collecting the material, edited the text of the paper

The authors have read and approved the final manuscript.

The authors declare that they have no conflict of interest.