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Coastal Vulnerability Study to Sea Level Rise in Padang City

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ABSTRACT

The coastal area of Padang City, which directly faces the Indian Ocean, has significant potential to be affected by sea level rise due to climate change. This study aims to analyze the vulnerability level of coastal areas in Padang City to sea level rise using the Coastal Vulnerability Index (CVI) method. The research was conducted in five coastal sub-districts: Koto Tangah, North Padang, West Padang, South Padang, and Bungus Teluk Kabung. The methodology integrates geomorphological analysis, tidal range, wave height, sea level rise, and shoreline change parameters. These data were obtained from field observations, BMKG records, and satellite imagery, which were processed through indexing and spatial mapping techniques to calculate CVI values. The results indicate that the coastal areas of Padang City fall into two vulnerability categories, namely low and moderate, with CVI values ranging from 2.82 to 7.07. Koto Tangah, North Padang, and West Padang sub-districts are classified as moderately vulnerable, while South Padang and Bungus Teluk Kabung fall into the low vulnerability category. These findings highlight the role of coastal physical characteristics in determining vulnerability levels and provide important insights for coastal management and mitigation strategies.

Keywords : Coastal Vulnerability, Sea Level Rise, CVI, Padang City, Climate Change.

I. INTRODUCTION

Geographically, two-thirds of Indonesia's territory is in the form of oceans, so Indonesia is called an archipelago. The length of Indonesia's coastline reaches 81,000 km, which is the second longest in the world after Canada [1]. Coastal areas are transitional areas that connect land ecosystems and marine ecosystems [2]. Historically, coastal areas have served as centers of community activity due to their physical and geographical advantages [3]. Coastal areas are very vulnerable to environmental pressures, both on land and in the ocean. One form of pressure that threatens the sustainability of coastal areas almost all over the world is the phenomenon of sea level rise.

Sea level rise is a phenomenon of rising sea levels caused by many factors, one of which is global warming [4]. The increase in population and industrial activity has led to an increase in greenhouse gas (GHG) emissions, leading to global warming. The biggest impact of this phenomenon is sea level rise, which threatens human life and coastal ecosystems. The phenomenon of sea level rise can have devastating effects on island nations [5]. This phenomenon can cause coastal erosion, coastal flooding, and damage to infrastructure such as houses, jetties, and other buildings. The worst threat is the submergence of coastal lands, resulting in loss of homes, livelihoods and loss of life [6].

Vulnerability is a condition that indicates or causes the inability of an ecosystem or community to cope with hazards. The level of vulnerability in each coastal area varies according to the disturbance received, either from natural factors or due to human activities (anthropogenic) [7]. The level of vulnerability is very important as one of the factors that influence the occurrence of disasters [8]. One of the vulnerabilities in coastal areas is rising sea levels. Sea water rise causes inundation of water to submerge several points of land areas that occur due to the overflow of sea water at high tide or known as tidal flooding [9]. Many areas in Indonesia today have the potential

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to experience inundation due to sea level rise, one of which is the city of Padang, which is the administrative center and the main economic driver area in West Sumatra.

Padang City is the capital city of West Sumatra Province, located on the west coast of West Sumatra and directly facing the Indian Ocean [10]. Apart from being the administrative center, Padang City is also one of the main economic areas in West Sumatra. The beach tourism sector is one of the main sources of community income. However, sea level rise has the potential to reduce the attractiveness of coastal tourism due to loss of coastal land, infrastructure damage, and the increasing threat of tidal flooding [11]. Thus, rising sea levels will cause some areas in coastal Padang City that are almost the same height as sea level to be predicted to be inundated. Sea Level Rise will have a direct impact on coastal areas [12].

Research on Coastal Vulnerability has been conducted previously. In the study conducted by Handiani et al. (2019) on coastal vulnerability to sea level rise in Subang Regency, West Java, the analysis showed that the overall Coastal Vulnerability Index (CVI) for all coastal districts was categorized as very low. However, localized assessments revealed that Sukasari and Blanakan districts exhibited very high levels of vulnerability. Furthermore, in the study by Gunawan and Handiani (2021) regarding coastal vulnerability in the northern coast of West Java, the results indicated that most areas were classified as not vulnerable. Nevertheless, Indramayu and Cirebon Regencies, along with Cirebon City, had more than 40% of their coastline falling into the moderate vulnerability category. Indramayu District recorded the highest CVI value of 47.246, indicating a vulnerable classification, whereas the lowest CVI value was found in Muaragembong District. Despite these studies, no research has specifically analyzed the level of coastal vulnerability in Padang City. In addition, previous studies generally relied on satellite imagery for data on sea level, wave height, and tidal range, without incorporating direct observational data.

Given the importance of coastal areas as key drivers of regional economic activity, further studies are needed to identify the level of vulnerability of Padang City's coastal zone to sea level rise. This is intended to provide a comprehensive overview of the potential impacts of the phenomenon and to formulate appropriate mitigation and adaptation strategies. Such efforts are expected to minimize associated risks while ensuring the sustainability of coastal ecosystems and the well-being of coastal communities in Padang City.

II. METHOD

The research location covers 5 coastal sub-districts of Padang City, namely Koto Tangah, North Padang, West Padang, South Padang, Bungus Teluk Kabung. The Coastal Vulnerability Index is constructed based on six physical coastal parameters, namely geomorphology, tidal range, average wave height, sea level rise, and shoreline change. Geomorphological data were obtained through direct observation by taking pictures in five sub-districts in coastal Padang City, namely Koto Tangah, North Padang, West Padang, South Padang, and Bungus Teluk Kabung. Each sub-district is represented by one data collection station point. The tide, sea level and wave height data came from BMKG Maritime Station class IV Teluk Bayur, Padang City. Meanwhile, the shoreline change data were obtained from the study conducted by Putra and Yulfa (2021).

The collected data were integrated to calculate the Coastal Vulnerability Index (CVI). The magnitude of coastal vulnerability was determined using the Coastal Vulnerability Index method. The obtained data were then classified into values according to Table 1. The classification results of all parameters were overlaid and incorporated into the calculation formula to determine the CVI.

$$CVI = \sqrt{\frac{a \times b \times c \times d \times e}{5}} \tag{1}$$

Where:
CVI = Coastal Vulnerability Index
a = geomorphology
b = average tidal range (m)
c = wave height (m)
d = sea level rise (mm/year)
e = shoreline change (m/year)

Table 1. Coastal Vulnerability Index assessment parameters and categories

Parameter	Vulnerability index				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
	1	**2**	**3**	**4**	**5**
Geomorphology	High cliff, rocky	Medium cliff, rocky	Medium cliff, rocky	Beach constructions, estuaries, lagoons	Sandy, muddy beaches, deltas
Average tidal range (m)	1	1,1-2,0	2,1-4,0	4,1-6,0	>6,0
Wave height (m)	< 0,55	0,55 – 0,85	0,85 – 1,05	1,05 – 1,25	> 1,25
Sea level rise (mm/year)	>1,8	1,8-2,5	2,5-3,0	3,0-3,4	>3,4
Shoreline change (m/year)	>2 (Accretion)	1,0-2,0 (Accretion)	-1-1 (Stable)	-1,0-(-2,0) (Erosion)	<-2 (Erosion)

(Source: Ref [13])

The data processed using the CVI method were further analyzed using ArcMap 10.8 software to perform line segmentation, allowing the classification of vulnerability levels based on each parameter's vulnerability class. The same procedure was applied to all parameters used in the CVI calculation. The classification of vulnerability categories based on CVI values is presented in Table 2.

Table 2. Determination of Vulnerability Category from CVI Value

CVI Value	**Vulnerability Category Level**
<4,75	Low
4,75-10,64	Moderate
10,65 – 19,66	High
>19,66	Very High

(Source: Ref [14])

III. RESULTS AND DISCUSSION

Result

1. Geomorphology

The results of geomorphological observations show that the coast of Padang City has a geomorphological form as shown in Figure 1. Where the coast of Padang City is divided into 2 vulnerability classes, namely rocky beaches with high cliffs (a) and sandy beach types (b). Which is categorized as very low (CVI = 1) and very high (CVI = 5) vulnerability classes.


(a)


(b)

Fig. 1. Coastal geomorphology of Padang City

Rocky and low cliff coastlines are generally found in the South Padang and in Bungus Teluk Kabung, while sandy beach types dominate the coastal areas of Koto Tangah, North Padang, and West Padang. This indicates that the coastal geomorphology of Padang City is predominantly composed of sandy beaches. These observations are consistent with the findings of [15], who stated that the coastal sediments along the shoreline of Padang City are largely composed of beach sand.

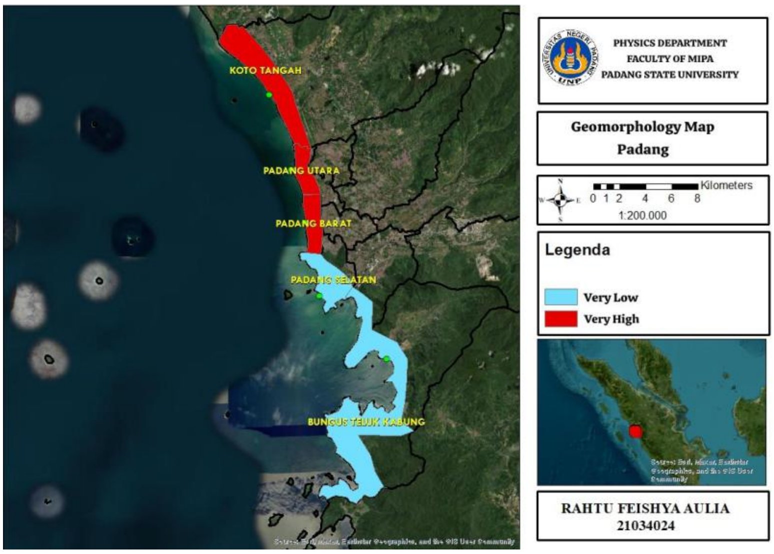

Fig. 2. Coastal Geomorphology Vulnerability Class Map

2. Average Tidal Range

Table 3. Average Tidal Range of Padang City

Years	Tidal Range (m)
2019	0,90
2020	1,53
2022	1.50
2023	1,68
2024	1,53
Average	1,41

According to [16], the average tidal type in Padang City is a double mixed tidal type where the shape value is $0.25 < F < 1.5$. This indicates the occurrence of two high tides and two low tides each day, with unequal heights and varying intervals. The average tidal range in Padang City, calculated from the difference between the mean maximum and minimum tide levels, is 1.41 meters. Based on the assessment, this value falls into the low vulnerability category (CVI = 2).

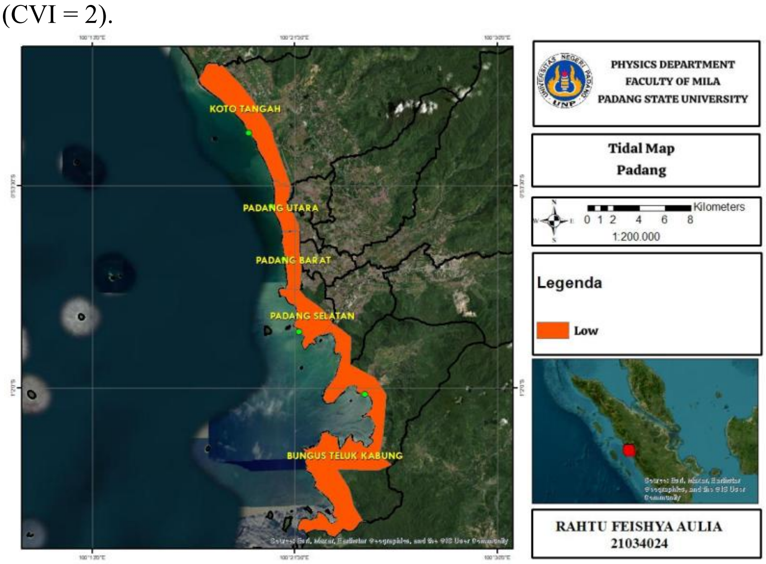

Fig. 3. Tidal Ridges Mean Vulnerability Class Map

3. Wave Height

Waves are a key parameter in the processes of coastal abrasion and sedimentation. The energy of the waves is primarily determined by their height. In the coastal waters of Padang City, the significant wave height—representing five coastal sub-districts—falls into the very low vulnerability category (CVI = 1), as the average significant wave height is below 0.55 meters.

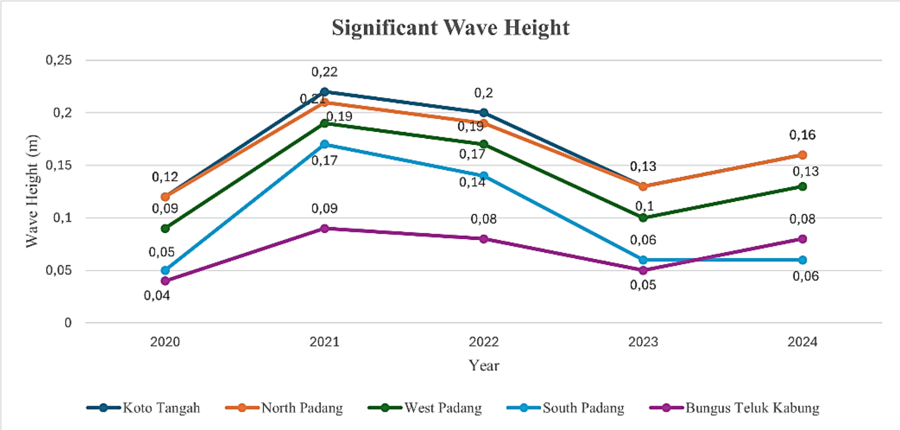

Fig. 4. Wave Height Chart of Padang City

Figure 4 illustrates the graph of significant wave heights, showing that Koto Tangah and North Padang tend to have higher wave heights compared to other areas. In contrast, Bungus Teluk Kabung consistently records the lowest wave heights each year.

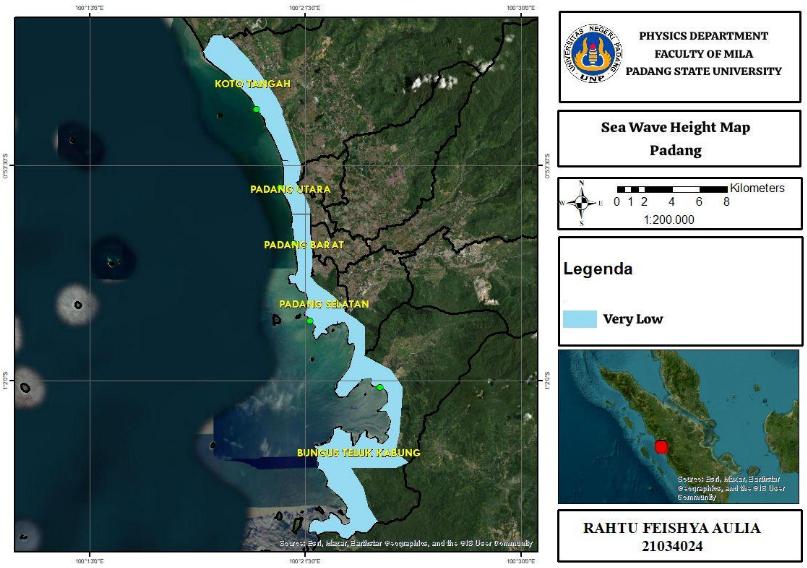

Fig. 5. Vulnerability Class Map of Mean Significant Wave Height

4. Sea Level Rise

The annual sea level data from 2019 to 2024 were plotted as a time series to observe the linear trend pattern. The predicted rate of sea level rise was derived using the linear equation Y = ax - b, where x represents time (in years), Y is the sea level (in meters), and a and b are constants [17]. The annual sea level rise data, as illustrated in Figure 6, were based on measurements collected during the 2019–2024 period.

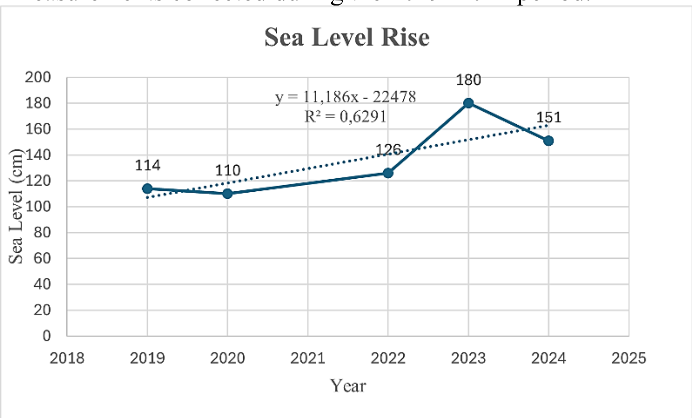

Fig. 6. Annual Sea Level Condition of Padang City Waters 2019-2024

The sea level rise trend follows a linear pattern with the equation Y = 11.186X - 22478 (R^2 = 0.6291). So, for 6 years (2019-2024), the value of sea level rise is 11.18 cm/year. The average sea level rise of 11.18 cm/year is purely the result of sea level calculations that are not corrected for land subsidence factors at the study site. This value is very high when compared to sea level rise data around the world measured in millimeters. However, the value of sea level rise presented in this study is an approach based on sea level rise from measured sea level data over a short period of time (6 years). Based on the results of this analysis, the coastal sea level rise of Padang City is included in the very high vulnerability class (CVI = 5).

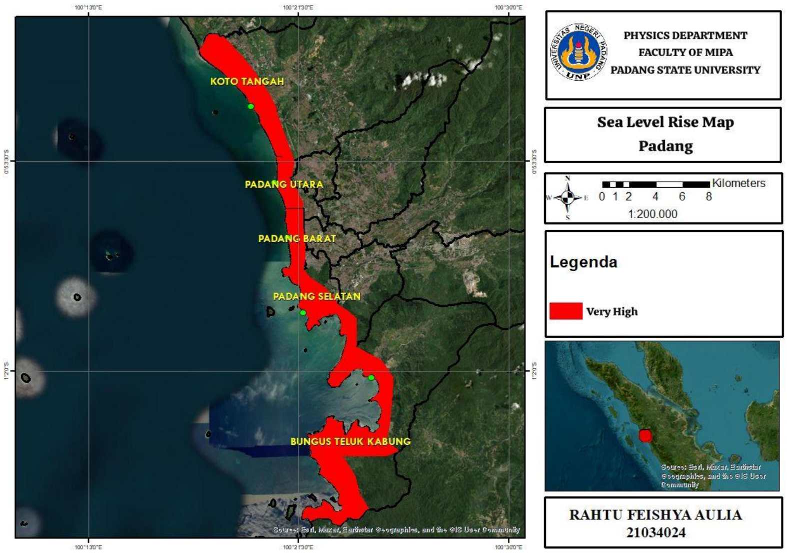

Fig. 7. Sea Level Rise Vulnerability Class Map

5. Shoreline Change

Shoreline changes in Padang City in the period 2015 to 2020 were dominated by abrasion, with an average abrasion rate of -3.58 m/year and an abrasion distance of -17.40m. Meanwhile, the accretion process was recorded at only 2.11 m/year. The data shows that the erosion of the coastline is much more significant than the addition of land. In addition, the pattern of this change varies from subdistrict to subdistrict, depending on the morphological condition of the coast and the oceanographic factors that influence it.

Table 4. Shoreline change value for 2015-2020

Sub-district	Average Distance (m)		Average Rate (m/year)		Dominant Event	Total Dominant Occurrence (m/year)
	(-)	(+)	(-)	(+)		
Koto Tangah	-22.96	11.03	-4.72	2.27	Erosion	-2,45
North Padang	-6.57	7.16	-1.35	1.47	Accretion	0,12
West Padang	-12.68	10.54	-2.61	2.17	Erosion	-0,44
South Padang	-22.24	9.11	-4.57	1.87	Erosion	-2,7
Bungus Teluk Kabung	-21.93	13.43	-4.52	2.77	Erosion	-1,75
Total	-17,27	10,25	-3,55	2,11	Erosion	-1,44

(Source: Ref [18])

Based on the results of this study, the changes in the coastline of Padang City fall into 3 categories of vulnerability classes, namely low vulnerability class (CVI = 2), high vulnerability class (CVI = 4) and very high vulnerability class (CVI = 5).

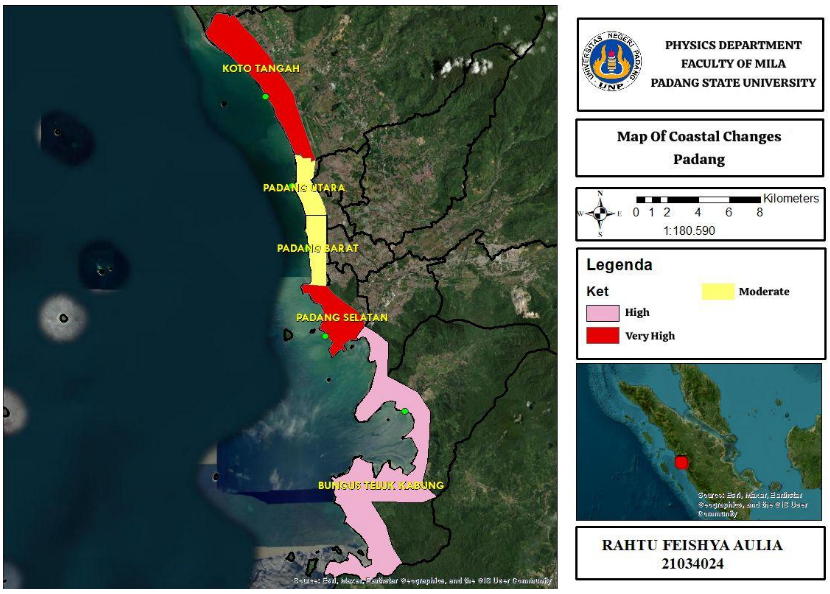

Fig. 8. Shoreline Change Vulnerability Class Map

6. **Coastal Vulnerability of Padang City**

The processing divides the vulnerability level into four classes: low, medium, high and very high.

Table 5. Calculation of CVI Index

Sub-district	CVI	Category
Koto Tangah	7,07	Moderate
North Padang	5,47	Moderate
West Padang	7,07	Moderate
South Padang	3,16	Low
Bungus Teluk Kabung	2,82	Low

The results of the analysis obtained the CVI value at 5 points which are considered representative of each coastal sub-district of Padang City ranging from 2.82 - 7.07. From the results of the analysis based on the calculation of CVI, it is found that the level of vulnerability on the coast of Padang City is at a low and medium level of vulnerability.

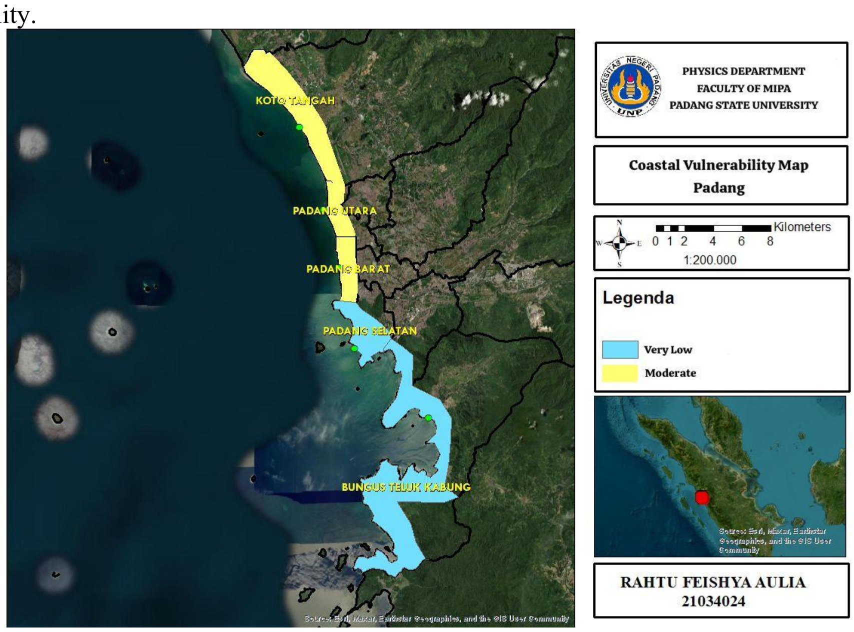

Fig. 9. Coastal Vulnerability Map of Padang City

Discussion

Based on the results of the CVI calculation of the coast of Padang City using geomorphological parameters, tides, wave height, sea level and shoreline changes. It was found that the coastal areas of Padang City are divided into two vulnerability level classes, namely moderate vulnerability and low vulnerability. Areas with moderate vulnerability include Koto Tangah, North Padang and West Padang sub-districts. Meanwhile, areas with low vulnerability are found in the sub-districts of South Padang and Bungus Teluk Kabung.

Based on geomorphological parameters, the coastal area of Padang City is categorized as very high vulnerability (CVI = 5) which covers Koto Tangah, North Padang, West Padang and very low vulnerability covers South Padang and Bungus Teluk Kabung. Areas with a very high level of vulnerability to sea level rise are generally influenced by geomorphological conditions dominated by sandy beaches, where coastal sediments are composed of sand material. Sandy beach is a type of beach that tends to be more vulnerable to abrasion [19]. In addition, there is no mangrove forest in the area. Mangroves are communities that live in wet and muddy areas and are influenced by tides. Mangroves have various functions, one of which is to prevent abrasion [20]. Meanwhile, areas with very low vulnerability (CVI = 1) to sea level rise generally have geomorphological conditions in the form of rocky and high cliff beaches, which are naturally more resistant to abrasion. In addition, the presence of mangrove forests in the Bungus Teluk Kabung area also provides natural protection against the impacts of sea level rise.

Based on the tidal parameter, the coastal area of Padang City falls into the low vulnerability class (CVI = 2). The tidal range in Padang City ranges from 0.90-1.68 m/year. In 2024 there was a significant increase in maximum tides, especially in June, the event was thought to occur due to the supermoon phenomenon. The supermoon phenomenon is a full moon phenomenon that occurs when the position of the moon is reaching the closest distance to the earth (lunar perigee) [21]. Sea tides arise mainly due to the gravitational pull of the earth against the moon and sun, while the contribution of the attractive forces of other planets is small. The magnitude of the rise and fall of sea levels depends on the position of the earth against the moon and sun [22].

Based on the wave height parameter, the coastal area of Padang City falls into the very low vulnerability class (CVI = 1). The significant wave graph shows that the further north Padang City goes, the higher the average significant wave becomes. This is because the north coast of Padang City tends to have sloping and open beaches, while the south coast of Padang City has a hilly topography and a bay shape. Beaches with steep topographic conditions such as hills can function as natural wave absorbers, because wave energy can be reflected, rather than absorbed or eroding the soil, while sloping and open beaches will be more vulnerable to the direct impact of ocean waves [23].

Based on the sea level parameter, the coastal area of Padang City falls into the very high vulnerability class (CVI = 5). The high rate of sea level rise in Padang City, which reaches more than 10 cm per year, may not only be influenced by global warming, but also by local factors such as land subsidence, regional ocean current dynamics, and anthropogenic activities in coastal areas. The rise in sea level influenced by tides causes tidal flooding that inundates low areas around the coast. Tidal floods are expected to become even greater due to the phenomenon of rising sea surface temperatures followed by the expansion of sea water masses and melting of ice sheets, thus accelerating sea level rise [24].

Based on the parameter of shoreline change, the coastal areas of Padang City fall into three categories of vulnerability classes: low vulnerability class (CVI = 2), high vulnerability class (CVI = 4) and very high vulnerability class (CVI = 5). Low vulnerability to shoreline change covers North Padang. Shoreline change in the North Padang area is dominated by accretion. Accretion is the movement of sediment that impacts the advancement of the coastline [25]. The accretion process in North Padang sub-district is generally not dominated by vegetative factors, given the limited presence of mangrove ecosystems in this area. Therefore, accretion may be more influenced by other factors such as sediment supply from rivers, local ocean current dynamics, as well as possible reclamation activities or the presence of artificial structures that cause localized sediment buildup.

Areas with high vulnerability to shoreline change include Bungus Teluk Kabung sub-district. Areas with very high vulnerability to shoreline change include Koto Tangah, West Padang and South Padang sub-districts. Shoreline changes in these areas are dominated by the abrasion process. Abrasion is the movement of sediment that causes significant retreat of the shoreline. Shoreline change in Padang City is dominated by abrasion. Abrasion in the area is significantly influenced by the speed of the longshore current, which transports sediment from wave action along the shoreline [26]. Waves coming towards the coast produce parallel coastal currents that have an important role in the sediment transportation process, both towards sedimentation and abrasion (Fajri et al., 2012). Padang Selatan sub-district experiences significant abrasion not because the waves are large, but because the vulnerability of the beach increases due to the absence of natural protection such as mangroves so that wave energy directly hits the shoreline and causes faster soil erosion.

The results of the mapping can be seen that the coastal areas of Padang City are at moderate and low vulnerability levels with a dominant level of moderate vulnerability. The CVI value in coastal Padang City ranges from 2.82 - 7.07. Areas with moderate vulnerability can still be categorized as safe areas, but if the area is not managed properly, it can become an area with high vulnerability [27].

IV. CONCLUSION

The analysis of coastal vulnerability in Padang City using the Coastal Vulnerability Index (CVI) method reveals that the region exhibits both moderate and low levels of vulnerability, with CVI values ranging from 2.82 to 7.07, where the moderate vulnerability zones are located in the coastal areas of North Padang, West Padang, and Koto Tangah, while the low vulnerability zones are found in South Padang and Bungus Teluk Kabung.

REFERENCES

[1] T. Mutiarawati and S. Sudarmo, "Collaborative Governance in Addressing Tidal Flooding in Bandengan Subdistrict, Pekalongan City", *Wacana Publik*, vol. 1, no. 1, pp. 82, 2021.
[2] M. Muharuddin, "The Role and Function of Government in Addressing Environmental Damage", *Justisi*, vol. 5, no. 2, pp. 97–112, 2019.
[3] A. Herison, Y. Romdania, and W. B. Yosua, "Zoning Analysis of Marine Ecotourism Based on Geographic Information Systems (Case Study: Pesisir Barat Regency)", *Jurnal Spatial Komunikasi dan Informasi Geografi*, vol. 18, no. 2, pp. 95–104, 2018.
[4] I. U. Khasanah, "Sea Level Rise in West Sumatra Waters Based on Jason-2 Altimetry Satellite Data", *Jurnal Ilmiah Geomatika*, vol. 23, no. 1, pp. 1, 2017.
[5] A. Shalsabilla, H. Setiyono, D. N. Sugianto, D. H. Ismunarti, and J. Marwoto, "Study of Sea Level Fluctuations as an Impact of Climate Change in the Waters of Semarang," *Indonesian Journal of Oceanography*, vol. 4, no. 1, pp. 69–76, 2022.
[6] N. A. Azuga, "Assessment of Coastal Area Vulnerability to Sea Level Rise Disasters in Indonesia", *Jurnal Riset Kelautan Tropis (Journal of Tropical Marine Research) – J-Tropimar*, vol. 3, no. 2, pp. 65–76, 2021.
[7] D. N. Handiani, S. Darmawan, A. Heriati, and Y. D. Aditya, "Assessment of Coastal Vulnerability to Sea Level Rise in Subang Regency, West Java", *Jurnal Kelautan Indonesia*, vol. 4, no. 3, pp. 145–154, 2019.
[8] N. R. Ramadhanty, C. Muryani, and G. A. Tjahjono, "Analysis of Community Vulnerability to Tidal Flooding in Tegal Barat District, Tegal City, in 2021", *Indonesian Journal of Environment and Disaster*, vol. 1, no. 1, pp. 73–82, 2022.
[9] A. A. Khoirunnisaa, A. M. Sariwardoyo, and A. B. Sinurat, "Coastal Vulnerability Analysis of Yogyakarta to Sea Level Rise and Tidal Flood Risk", *Indonesian Conference of Maritime*, vol. 1, no. 1, pp. 297–311, Dec. 2022.
[10] Y. P. Putri, "Policy Direction on Flash Flood Disaster Mitigation in the Kuranji Watershed, Padang City," *Majalah Ilmiah Globe*, vol. 20, no. 2, pp. 88, 2018.
[11] M. H. Rasyda, S. Widada, and B. Rochaddi, "Spatial Analysis of Tidal Flood (Rob) Areas Caused by Sea Level Rise in Padang City," *Journal of Oceanography*, vol. 4, no. 2, pp. 379–385, 2015.
[12] F. Putra, H. Haryani, and E. Aditia, "Development of Coastal Spatial Planning Based on Sea Level Rise Mitigation: A Case Study of Padang City's Coastal Area," *Abstract of Undergraduate Research, Faculty of Civil and Planning Engineering, Bung Hatta University*, vol. 1, no. 1, 2018.
[13] L. F. Yuliastini, M. Zainuri and R. Widiaratih, "Analysis of Coastal Vulnerability in Kendal Regency", Indonesian Journal of Oceanography, vol. 5, no. 1, pp. 80-89, 2023.
[14] M. P. Suhana, I. W. Nurjaya, and N. M. N. Natih, "Analysis of the Eastern Coastal Vulnerability of Bintan Island Using Digital Shoreline Analysis and Coastal Vulnerability Index", *Journal of Fisheries and Marine Technology*, vol. 7, no. 1, pp. 21–38, 2016.
[15] B. Istijono, "Environmental Review and Coastal Abrasion Mitigation in Padang-West Sumatra", *Civil Engineering Journal*, vol. 9, no. 2, pp. 42–49, 2013.
[16] A. Suanda, D. M. Driptufany, D. Defwaldi, F. Fajrin, and I. Armi, "Spatial Modeling of Flooding Due to Sea Water Rise (Rob) in Padang City", *Aerospace Engineering*, vol. 1, no. 2, p. 19, 2024.
[17] G. D. Kresteva, B. Rochaddi, and A. Satriadi, "Study of Sea Level Rise in Kendal Waters", *Journal of Oceanography*, vol. 3, no. 4, pp. 535–539, 2014.

[18] B. G. Putra and A. Yulfa, "Identification of MNDWI Usage in the Dynamics of Coastal Line Changes in Padang City from 2015 to 2020", JURNAL BUANA, 2021.

[19] S. Syahrul, A. Salim, and R. Ruslan, "Disaster Mitigation Analysis of Coastal Abrasion in Galesong Subdistrict, Takalar Regency", *Journal of Urban Planning Studies*, vol. 1, no. 1, pp. 30–41, 2020.

[20] E. K. Rinjani, S. Panbriani, U. Auliya'Amalina, and I. P. Artayasa, "Coastal Abrasion Disaster Mitigation Through Mangrove Planting in Seriwe Village, East Lombok", *Journal of Community Service for Science Education*, vol. 5, no. 1, pp. 226–230, 2022.

[21] S. H. Tiatama, W. Atmodjo, and R. Widiaratih, "Analysis of the Relationship Between the Supermoon Phenomenon and Tidal Components in Semarang Waters, Central Java", *Indonesian Journal of Oceanography*, vol. 6, no. 2, pp. 114–120, 2024.

[22] T. Tanto and I. Ilham, "Study of Oceanographic Parameters in the Marine Conservation Area of Padang City to Support Marine Tourism (Case Study: Bindalang Island and Sibonta Island)", *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, vol. 16, no. 2, pp. 191–202, 2023.

[23] C. Purwanto and P. Raharjo, "Environmental Geology of the Coastal Area of the Outermost Small Island of Miangas, Talaud Islands Regency, North Sulawesi", *Journal of Marine Geology*, vol. 13, no. 1, Article ID 230387, 2016.

[24] U. Efendi, A. Kristianto, and B. E. Pratama, "Response of Heavy Rainfall and Sea Level Rise to the Predicted Extent of Tidal Flooding in Semarang (Case Study of December 3–5, 2018)", *Jurnal Kelautan Nasional*, vol. 16, no. 3, pp. 157–168, 2021.

[25] R. Aldian, E. Zuryani, and A. Z. P. Ulni, "Coastal Line Change Due to Abrasion and Accretion in the Coastal Area of West Sumatra," in *Social, Humanities, and Educational Studies (SHES): Conference Series*, vol. 5, no. 4, pp. 152–161, 2019.

[26] F. Fajri, R. Rifardi, and A. Tanjung, "Study of Coastal Abrasion in Padang City, West Sumatra Province", *Journal of Fisheries and Marine Science*, vol. 17, no. 2, Article ID 296062, 2012.

[27] F. A. Loinenak, A. Hartoko, and M. R. Muskananfola, "Mapping of Coastal Vulnerability Using the Coastal Vulnerability Index and Geographic Information System", *International Journal of Technology*, vol. 5, pp. 819–827, 2015.