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Coastal Geomorphological Dynamics and Tsunami Hazard Zones (5–12 m ASL) in Padang City, West Sumatra, Indonesia

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ABSTRACT
Padang City is one of the capital cities in the western part of the island of Sumatra, with a total coastline length of approximately 68,126 km and directly adjacent to the Indian Ocean. The last time the province of West Sumatra was hit by a tsunami was in 2009 and 2010, which caused tsunamis with heights of <1 metre to >12 metres caused by an earthquake with a magnitude of 7.9. Experts estimate the potential for earthquake disasters originating from megathrust plate faults along the Mentawai Islands. Early and optimal mitigation efforts can minimise the impact caused by tsunami disasters. This study aims to provide an overview of the influence of shoreline changes on the tsunami distribution zones of 5 and 12 metres above sea level. This research uses the coastline parameters of Padang city from 2005 to 2021, obtained from Google Earth, administration, slope and land cover, which will be processed by utilising the Geographic Information System in ArcGIS software. The method used in the research is Tsunami Inundation by dividing the height of tsunami inundation into three scales, including low, medium and high. Observations were made at 122 observation points spread along 18,520 metres of coastline of the study area. The results show that there are five to six sub-districts in Padang city that are affected by tsunami disasters of 5 and 12 metres above sea level, including the sub-districts of South Padang, East Padang, West Padang, North Padang, Nanggalo, and Koto Tangah. The difference in coastline from 2005 to 2021 shows a change in the area of the tsunami disaster distribution zone of around 78.69 to 91.51 hectares at each water level caused by accretion events that occur along the coastline of the observation area.

Keywords: Coastline, Earthquake, Tsunami, Disaster Mitigation.

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Introduction

Dynamic coastlines cause the shape and space of coastal areas to change rapidly as a result of natural processes and human activities around the coast. Through coastal abrasion and accretion events, the coastline changes endlessly due to sediment movement, changes in currents, wave activity and land use [1]. Abrasion can occur in coastal areas due to wave action, changes in currents, tidal variations and climate change [2]. Abrasion causes a decrease and inundation of the land surface by water, so that the coastline can change [3].

Meanwhile, accretion is an event of changing the coastline towards the open sea due to the process of sedimentation on land areas, the process of sediment transport from river bodies to the sea and human activities in managing land. Accretion can cause siltation in the sea area. Accretion usually occurs on beaches that have many river mouths [4]. Surveillance of coastal areas is a form of protection for a country and the environment. Surveillance of the coastline is something that can be utilised in managing coastal areas and developing coastal areas [5].

It is recorded that 90 per cent of tsunami events are caused by tectonic earthquakes, and tsunami waves cause the displacement of water in the middle of the sea to rise towards land. This causes damage and loss of life. Tsunamis are disasters whose impact can be reduced by managing disaster risk [6]. The mitigation process is very important in planning the development of an area, especially for Indonesia, which is vulnerable to natural disasters [7]. Experts predict the earthquake potential in the Mentawai segment of West Sumatra province to be around 8.8 SR [8].

This is based on historical records of West Sumatra province in 1797, which was hit by an earthquake with a magnitude of 8.4 SR, which caused tsunami waves estimated at a height of 5-10 metres or about 1 km inland. Then, in 1833, the rupture of the 1000 km long Sumatra trough caused by an earthquake with a magnitude of 9.0 SR caused a tsunami with a water height of 2-3 metres [9]. It was reported that an earthquake on 30 September 2009 with a magnitude of 7.6 occurred in the city of Pariaman, about 1,117 people were killed and 181,665 buildings were destroyed by the earthquake, there was a run up of tsunami waves < 1 metre including in the eastern part of the Mentawai islands [10].

The latest earthquake with a magnitude of 7.7 shook the Mentawai Islands. Researchers made observations and obtained run-up height values on the island of Cypora around 1 to 4 metres, Pagai island 2.4 to 8 metres and South Pagai island 2.5 to 12.4 metres. The highest run-up was found in the Sibigou area with a height of about 12.4 metres [10]. Padang City is one of the provincial capitals located on the western edge of Sumatra Island. Due to the geographical condition of the lowlands, many community activities are centred around the coast. Many vital objects that encourage all community activities are in the area around the coast of Padang city [11].

Coastal Geology and Geomorphology. The geology of Padang city consists of surface deposits, intrusions, volcanic rocks, sedimentary rocks and metamorphic rocks (Figure 1). The Padang City area is composed of 4 rock layers consisting of Jurassic age sedimentary rocks, Quaternary age sedimentary rocks and volcanic rocks. The coast of Padang City consists of surface deposits, intrusions, volcanic rocks, sedimentary rocks and metamorphic rocks [11].

Padang City is one of the developing areas on the western coast of Sumatra Island. This area has 11 sub-districts with 104 villages in it. Padang City is the provincial capital of West Sumatra. This area has an area of around 694.96 km^2 with geographical conditions bordering the Indian Ocean. In the north, the area is bordered by Padang Pariaman district, in the south by Pesisir Selatan district and in the east by Solok district. In the western part of the Padang city area lies lowland, while in the eastern part of the Padang city area lies a row of hills and the Padang city area is traversed by 21 rivers [13].

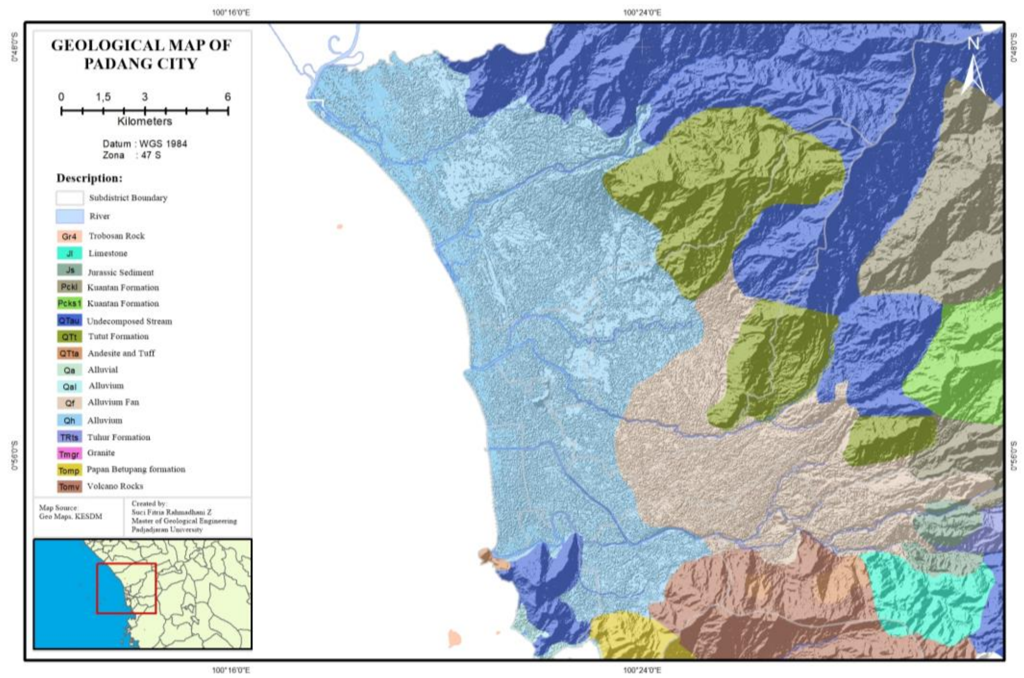


Figure 1 - Coastal geological map of Padang city

There is andesite and tuff that can be exposed around the Pengambiran area and cold water hills, in the form of greyish black and white volcanic rocks. In the west, there are andesite rock fragments in the form of chunks of volcanic origin with a blackish grey colour, scattered at the bottom of the slopes of Nago and Limau Manis hills. In the western part of the lowlands of the observation area, deposits of silt, clay, gravel and loamy sand and finally undecomposed volcanic-derived rocks generally consist of conglomerate, breccia and sandstone. These deposits are scattered around Bukit Barisan, Gunung Padang and Bukit Air Manis [12].

The land area of Padang city has an altitude between 0 to >1000 masl. The coast of Padang city forms a straight beach with alluvium lowlands. The shape of the beach around the mouth of the river is in the form of sand spits. The beach sediments that make up the coastal area mostly consist of sand. Around the mouth of the river estuary, there is active sedimentation. The coast of Padang city is classified as a type of high-energy beach that is >2 metres, which usually occurs during the west wind season [14].

The youngest rocks in the Padang City area are alluvium deposits consisting of layers of sand, silt, gravel and swamp deposits. Older sedimentary rocks consist of metamorphic rocks and limestone. In the eastern and southern hilly areas, there are volcanic rocks consisting of basaltic lava, breccia and andesitic tuff [15]. The shape of the beach around the mouth of the river in the Padang City area is in the form of sand spits. The sediments that make up the beach area consist mostly of sand. Around the mouth of the river, there is also active sedimentation.

The mainland of Padang City has an altitude between 0 to >1000 metres above sea level. On the coast of Padang City, it forms a straight beach with a landscape of alluvium lowlands as shown in Figure 2. Land cover is any appearance of physical material that exists on the Earth's surface. Land cover can illustrate the relationship between natural processes and social processes. Land cover provides information that can be used to understand natural events or phenomena on the Earth's surface [16].

Land use is any form of human interference with natural resources, whether temporary or permanent. Aiming to fulfil all needs in the form of material or spiritual [17]. In the Padang City area, Figures 2 and 3 show the land cover and land use around the coast in the form of vacant land, shrubs, settlements and water bodies. There are 6 river estuaries along the observation area in Padang City, which can be seen in Figure 2.

Ocean Waves. Ocean waves are a perpendicular movement of the rise and fall of sea water with the surface of the sea water and form a curvilinear tidal [18]. Sea waves occur due to generating forces, these forces arise from wind, tides and earthquakes [19]. Data on the average wave height in coastal areas obtained from satellite image recordings on Copernicus show that in 2005 and 2021, as shown in Figures 4 and 5.

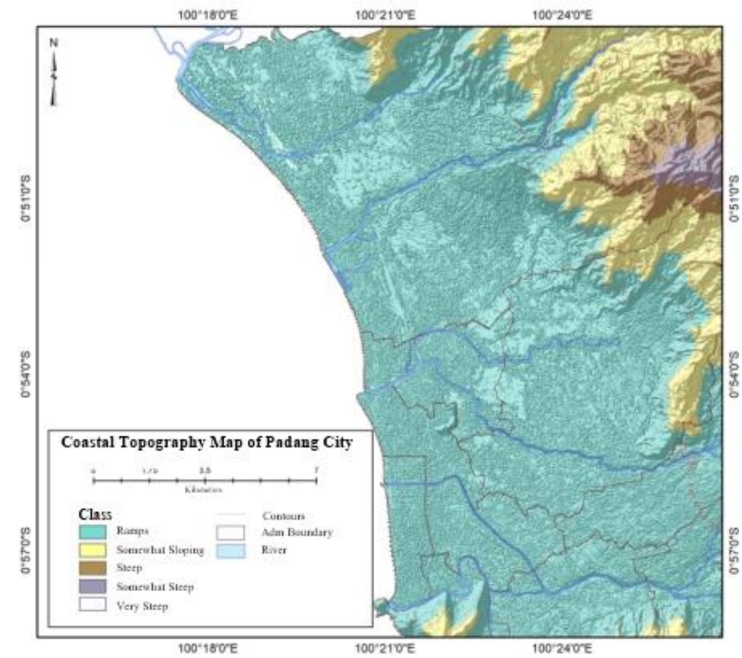


Figure 2 - Coastal Topography Map of Padang City

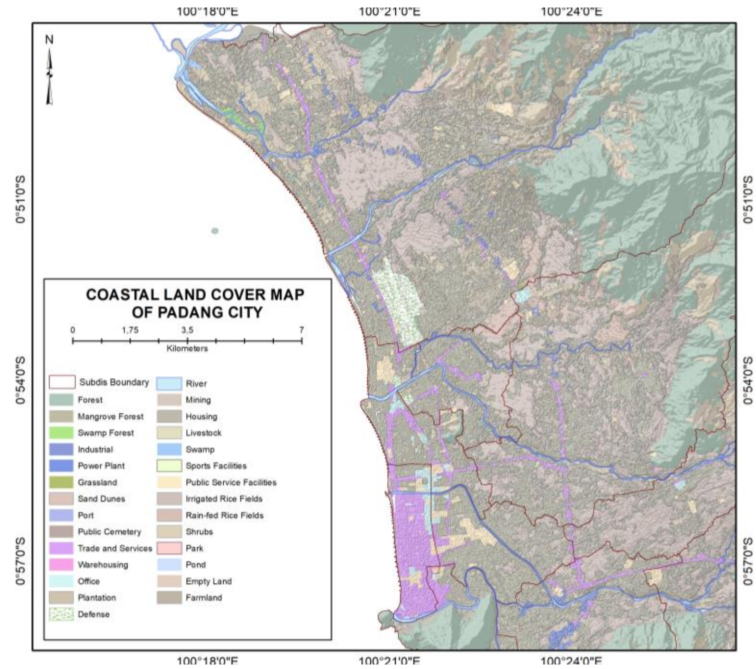


Figure 3 - Coastal Land Cover Map of Padang City

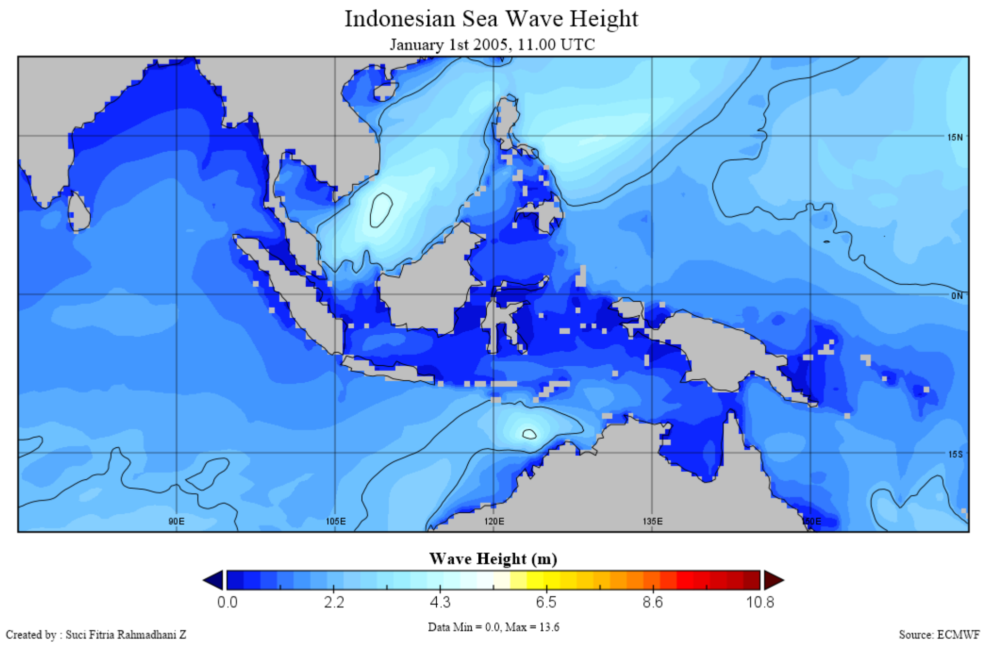


Figure 4 - Indonesian Sea Wave Height in 2005

In 2005, the area around the west coast of Sumatra Island had wave heights in the range of 0.4 - 0.6 metres. In Figure 4 above, it can be seen that Padang City, which is located in the western part of Sumatra Island, also has wave height values in the range of 0.4 - 0.6 metres. The average wave direction ranges from 180 - 216 degrees South Southwest.

Satellite image data on Copernicus in 2021 shows that the wave height around the west coast of Sumatra Island is in the range of 0.1 - 0.2 metres. In Figure 5 above, it can be seen that Padang City, which is in the western part of Sumatra Island, also has a wave height value in the range of 0.1 - 0.2 metres. The average wave direction ranges from 216-252 degrees Southwest. The wave height in the coastal area of Padang City is classified as low waves with rippling water, and there is no foam at the peak of the wave [20].

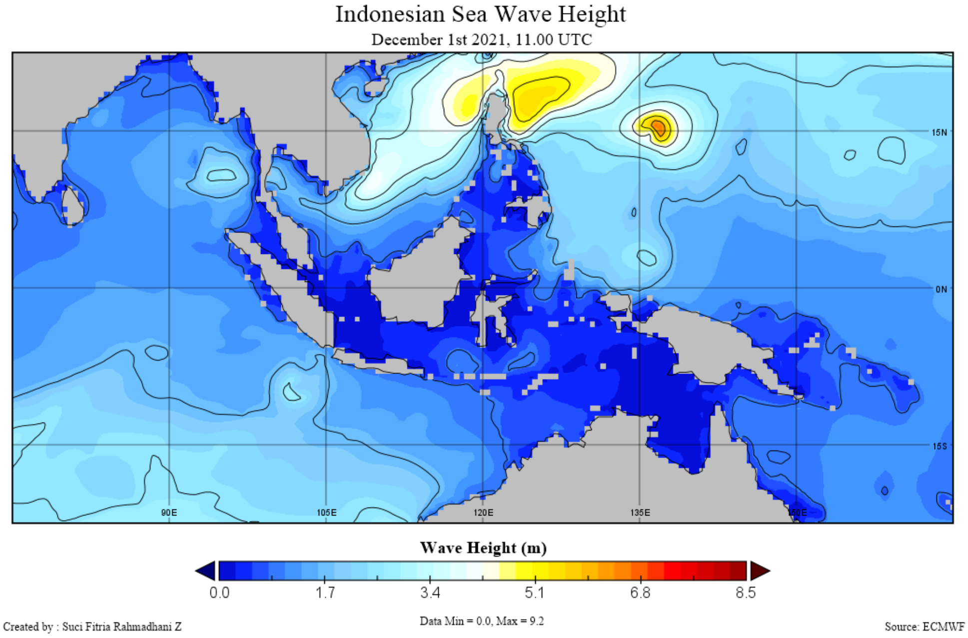


Figure 5 - Indonesian Sea Wave Height in 2021

Methods and Materials

This research was carried out only in the coastal area of the city of Padang, which has quite dense human activities, covering an observation area with a coastline length of around 18,520 metres. The method used is tsunami inundation in ArcGIS by processing variables such as coastline, administration, land cover and use and slope slope which then produces a tsunami rise model starting from the coastline in the observation area. The formula that will be processed has been determined [21] as follows;

Surface roughness is the value that each land cover and land use has when inhibiting seawater travelling inland during a tsunami. Surface roughness values have different values. The surface roughness value of each cover and land use can be seen in Table 1.

High resolution imagery on the Google Earth platform was used to extract the coastline from 2005 to 2021 to estimate variations and changes in the coastline. Estimated resolution up to 2 metres, the shoreline reference boundary used is the last area exposed to tidal waves clearly recorded on Google Earth images, which are then interpreted and digitised on the image screen with an eye rate of about 40 metres. This study aims to determine the effect of changes in coastal morphology on changes in tsunami disaster distribution zones at 122 observation points in Padang city.

Table 1 - Surface roughness coefficient values

Type of Land Cover and Use	Hardness Coefficient Value
Water body	0.007
Shrubs	0.040
Forest	0.070
Agriculture	0.035
Farmland	0.025
Vacant Land	0.015
Settlements	0.045
Mangrove Forest	0.025
Pond	0.010

Source: Berryman, 2006 [28]

Results

Through the USGS website, earthquakes with large to small magnitudes have hit the province of West Sumatra. The largest magnitude recorded by the USGS was 7.9 on the high seas [22].

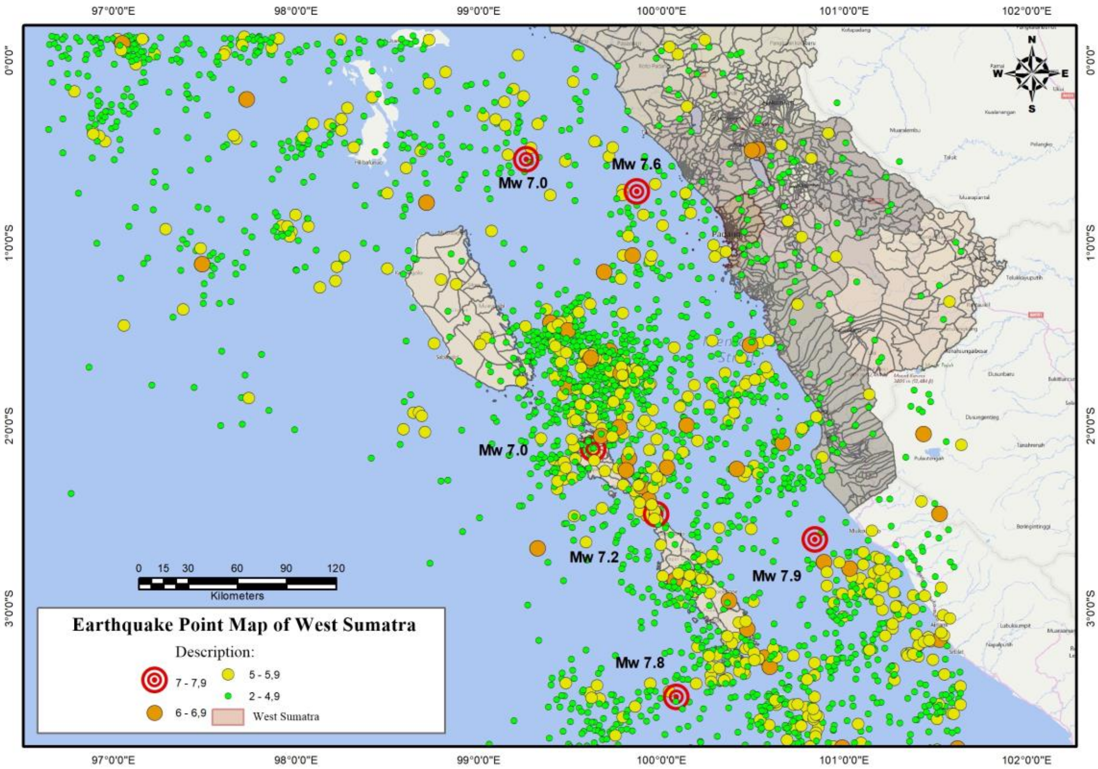


Figure 6 - Earthquake Point Map of West Sumatra Province (source: USGS, 2022)

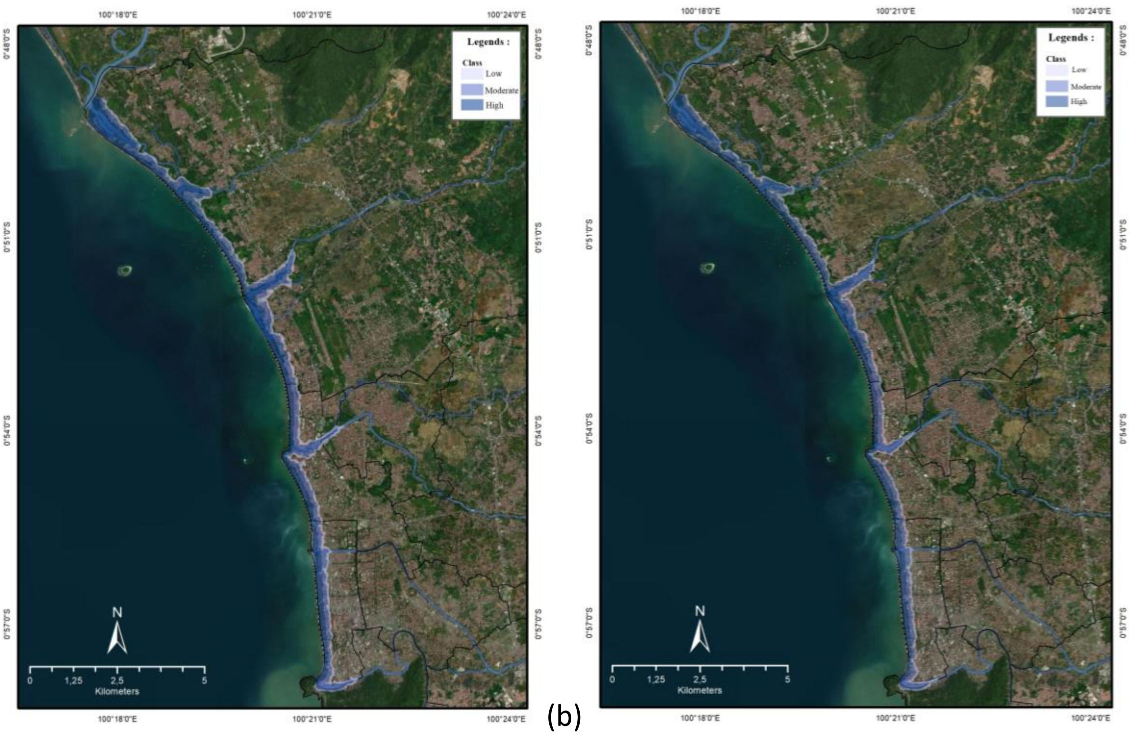
The reported earthquake on 30 September 2009 with a magnitude of Mw 7.6 occurred 25 km northwest of Pariaman city. At least 1,117 people were killed and 181,665 buildings were destroyed, about 451,000 people were displaced, and tsunami wave run-ups at heights below 1 metre included the eastern part of the Mentawai islands [23].

Then on 25 October 2010, an earthquake with Mw 7.7 shook the Mentawai islands, West Sumatra. The earthquake was centred off the southwest coast of Pagai Island. Researchers conducted observations on the 2010 tsunami, and obtained run-up height values on Sipora island of 1 - 4 metres, on North Pagai island of 2.4 - 8 metres and South Pagai island of 2.5 - 12.4 metres. The highest run-up height is found on Sibigou island with a run-up height of about 12.4 metres [10]. Research conducted by the Indonesian Institute of Sciences in 2010 on the western Mentawai segment on Siberut island was predicted to hold the potential for an earthquake of around 8.8 SR [8].

Statistical analysis was conducted based on the data of earthquake release energy and storage energy in the Mentawai segment area, which annually produces a total energy of 1.025 x 1022 erg or equivalent to 6.8 SR. Meanwhile, the potential energy of the earthquake on the Mentawai segment is 3.59 x 1022 erg, equivalent to 7.2 SR [24].

Tsunami Rise Model 5 Metres Above Sea Level. There are three scales of tsunami distribution zones 5 metres above sea level, including low, medium and high scales. Inundation of < 1 metre is a low scale, inundation of 1-3 metres is a medium scale and > 3 metres is a high scale tsunami distribution. An overview of the tsunami forecast 5 metres above sea level from the coastline in 2005 and 2021 can be seen in Figure 7.

Five sub-districts in Padang city were estimated to be affected by the tsunami distribution of 5 metres above sea level on the coastline in 2005, with different areas affected, including Padang Selatan, Padang Barat, Padang Utara, Nanggalo and Koto Tangah sub-districts. The estimated tsunami travel distance is between 145 metres and 1,743 metres towards the mainland of Padang city, with the largest total area affected in Koto Tangah sub-district, which is about 470 hectares of affected land, and the least affected area is in East Padang sub-district, which is about 9 hectares of affected land.



(a) (b)

Figure 7 - Tsunami landfall zone 5 metres above sea level from the shoreline
(a) Shoreline in 2005 (b) Shoreline in 2021

Table 2 - Tsunami Disaster Land Area 5 metres above Sea Level at the Coastline in 2005 by Subdistrict

District	Low Area (hectares)	Medium Area (hectares)	Height Area (hectares)
Padang Selatan	4.972885	5.642311	0.38253
Padang Barat	31.463059	65.79509	67.133943
Padang Utara	40.069975	68.759694	59.292087
Nanggalo	7.17243	2.00828	0
Koto Tengah	86.738585	175.389818	208.19173

Five sub-districts in Padang city are predicted to be affected by a tsunami rise of 5 metres above sea level on the coastline in 2021, with different areas affected, including Padang Selatan, Nanggalo, Padang Barat, Padang Utara and Koto Tangah sub-districts. The estimated tsunami travel distance is about 173 metres to 1,595 metres towards the mainland of Padang city, with the largest total distribution hitting Koto Tangah sub-district, which is about 425 hectares of affected land and the least affected area of tsunami distribution is in East Padang sub-district, which is about 2 hectares of affected land.

Table 3 - Tsunami Disaster Land Area 5 metres above Sea Level on the Coastline in 2021 by Sub-district

District	Low Area (hectares)	Medium Area (hectares)	Height Area (hectares)
Padang Selatan	5.365604	4.047737	0.188267
Padang Barat	30.969892	60.527783	67.399522
Padang Utara	33.040827	62.881119	52.99711
Koto Tengah	83.496336	161.627067	180.830283
Nanggalo	2.447469	0	0

Tsunami Rise Model 12 Metres Above Sea Level. There are three scales of tsunami distribution zones 12 metres above sea level, including low, medium and high scales. At < 1 metre the distribution scale is low, inundation with a height of 1-3 metres is medium, and > 3 metres is a high tsunami distribution scale. An overview of the tsunami forecast 5 metres above sea level from the coastline in 2005 and 2021 can be seen in Figure 8.

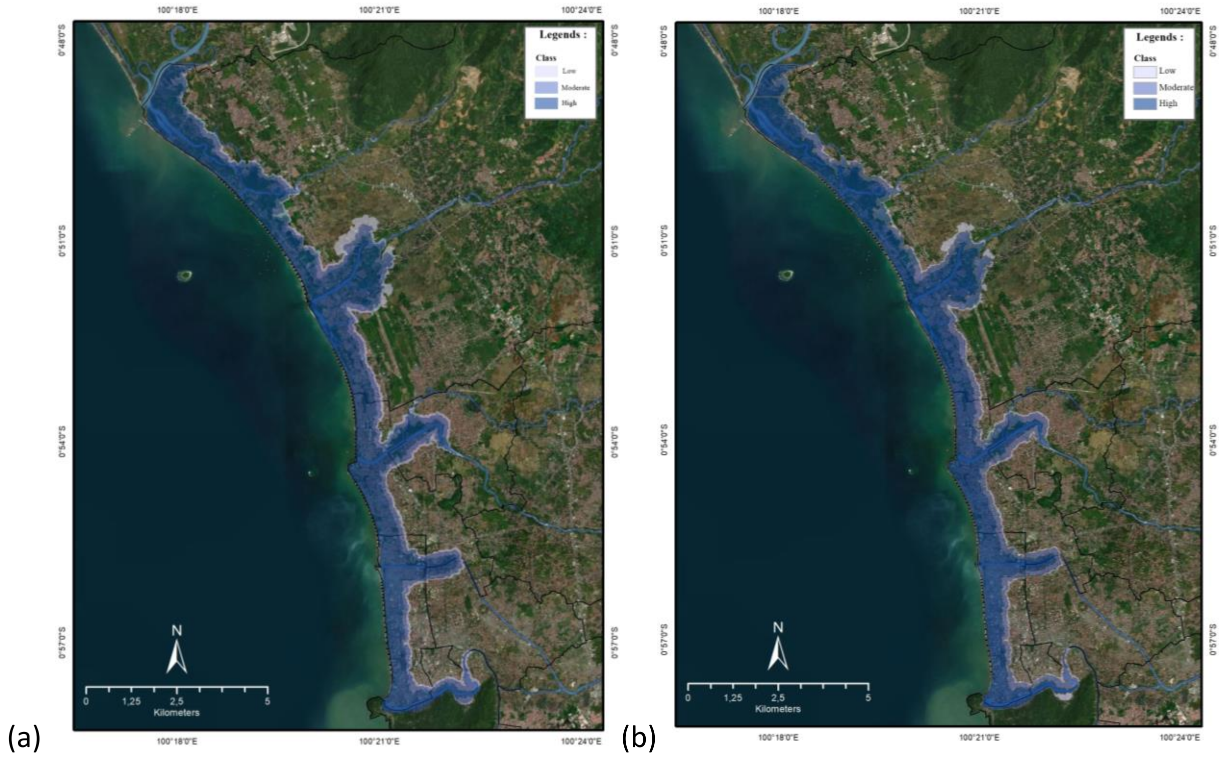


Figure 8 - Tsunami landfall zone 12 metres above sea level from the shoreline (a)Shoreline in 2005 (b) Shoreline in 2021

Table 4 - Tsunami Disaster Land Area 12 metres above Sea Level at the Coastline in 2005 by Subdistrict

District	Low Area (hectares)	Medium Area (hectares)	Height Area (hectares)
Padang Selatan	16.587256	32.095666	46.794942
Padang Timur	9.979325	15.238699	20.632928
Padang Barat	26.431725	56.504556	310.707628
Padang Utara	34.118503	69.450707	280.365086
Nanggalo	28.859129	51.91946	62.573064
Koto Tengah	141.059106	221.433127	841.904394

The six sub-districts in Padang city that were estimated to be affected by the tsunami of 12 metres above sea level at the 2005 coastline, with different areas affected include Padang Selatan, Padang Timur, Padang Barat, Padang Utara, Nanggalo and Koto Tangah sub-districts. The estimated tsunami distance is between 527 metres and 2,703 metres towards the mainland of Padang city, with the largest total area affected in Koto Tangah sub-district, which is about 1,204 hectares of affected land, and the least affected area is in East Padang sub-district, which is about 45 hectares of affected land.

Table 5 - Tsunami Disaster Land Area 12 metres above Sea Level on the Coastline in 2021 by Sub-districts

District	Low Area (hectares)	Medium Area (hectares)	Height Area (hectares)
Padang Selatan	14.055675	26.746722	44.623357
Padang Timur	8.324235	14.874452	16.784932
Padang Barat	27.15611	57.314404	305.676819
Padang Utara	25.24563	57.041478	246.042547
Nanggalo	17.740173	28.657202	36.026197
Koto Tengah	118.040379	212.745608	355.895154

Six sub-districts in Padang city are predicted to be affected by a tsunami of 12 metres above sea level on the coastline in 2021, with different areas affected, including Padang Selatan, Padang Timur, Padang Barat, Padang Utara, Nanggalo and Koto Tangah sub-districts. The estimated tsunami travel distance is about 525 metres to 2,693 metres towards the mainland of Padang city, with the largest total distribution hitting Koto Tangah sub-district, which is about 686 hectares of affected land and the least affected area of tsunami distribution is in East Padang sub-district, which is about 39 hectares of affected land.

Discussion

Shoreline change is a result of abrasion and accretion events on the coast [25]. Abrasion is a process of coastal erosion caused by destructive wave power and ocean currents [26]. Abrasion can occur in marine areas due to wave action, changes in current patterns, tidal variations, and climate change [2]. Abrasion causes a decrease and inundation of the land surface by water, so that the coastline can change [3].

Accretion is an event that changes the coastline towards the open sea due to the process of sedimentation from the land area caused by freshwater runoff with a large enough volume due to prolonged rain, and the process of sediment transport from river bodies to the sea, and due to human activities in managing land. Accretion can cause siltation evenly towards the sea, which will form a plain in the form of a delta or raised land. Coastal accretion usually occurs in coastal waters that have many river mouths and coastal waves with small energy and areas that rarely experience storms [4].

The research area in Figure 8 is divided into 4 stations or sections to review shoreline changes more accurately. Using images on Google Earth with a spatial resolution of up to 2 metres. The coastline along 18,520 metres obtained from the results of Google Earth digitisation with an eye of 70 m, then the coastline in KML format is inputted and processed using ArcGIS. The observation line was taken by measuring the observation distance of 150 metres between points on the 2005 coastline, as the first coastline observed.

Based on observations at 122 points of shoreline change from 2005 to 2007, there are 67 abrasion points with an average value of -8.16 and 55 accretion points with an average value of +7.73 metres. While on the coastline from 2007 to 2014, there are 49 abrasion points with an average value of -12.18 and 73 accretion points with an average value of +12.22 metres.

On the coastline from 2015 to 2017, there were 63 abrasion points with an average value of -5.15 metres and 59 accretion points with an average value of +5.33 metres. The 2017 to 2021 coastline has 78 abrasion points with an average value of -9.96 metres and 44 accretion points with an average value of +4.55 metres. Overall on the 2005 to 2021 coastline, 58 abrasion points with an average value of -17.60 metres were calculated, while there were 64 accretion event points with an average value of +13.06 metres. With a maximum value of abrasion events on the 2005 to 2021 coastline of around -68.25 metres and accretion of around +122.22 metres.

The Effect of Abrasion and Accretion on Changes in the Tsunami Landfall Zone 5 Metres Above Sea Level. At a tsunami landfall of 5 metres above sea level on the coastline from 2005 to 2021, there were 19 observation points that experienced abrasion with an average value of 23.38 metres, which caused a change in tsunami landfall distance of around 16.64 metres towards the mainland of Padang city.

The points that affect the change in the landfall zone are located at 11 points in Koto Tangah sub-district, 5 points in North Padang sub-district and 3 points in West Padang sub-district. While the accretion event on the coastline of Padang city occurred at 48 observation points with an average accretion of about 15.74 metres, and caused a change in the tsunami landfall distance of about 25.08 metres towards the sea. The difference in the area affected by the tsunami at 5 metres above sea level can be seen in Figure 9.

The area in red is the difference in the area affected on the coastline in 2005 and 2021, calculated and analysed using multivariate regression on coastline variables in the form of abrasion and accretion events on coastline changes at a tsunami landfall of 5 metres above sea level. Based on the R Square value of 0.095, it indicates that the effect of variables X1 and X2 together on variable Y is 9.5%. This explains that the geology of the observation area only significantly influences the tsunami coverage zone of 5 metres above sea level by only 9.5%. There is a change in the overall land area in the form of a reduction in the tsunami land area of 78.69 hectares from 2005 to 2021 due to accretion events.

The Effect of Abrasion and Accretion on Changes in the Tsunami Landfall Zone 12 Metres Above Sea Level. At a tsunami landfall of 12 metres above sea level, with the coastline from 2005 to 2021, 23 observation points experienced abrasion of around 23.41 metres, which caused a change in the tsunami landfall distance of around 23.87 metres towards the mainland of Padang city. The points that affect the change in the landfall zone are 18 points in Koto Tangah sub-district, 3 points in North Padang sub-district and 2 points in West Padang sub-district. The landfall points depicted in each region can be seen in Figure 10.

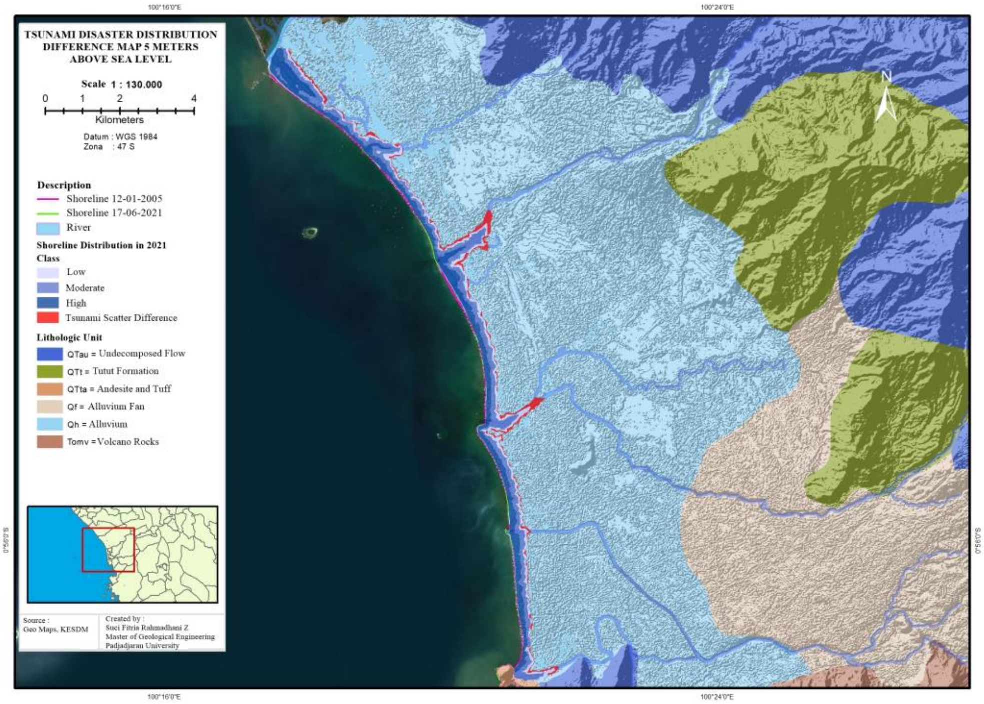


Figure 9 - Difference in Tsunami landfall zones of 5 metres above sea level at 2005 and 2021 coastlines

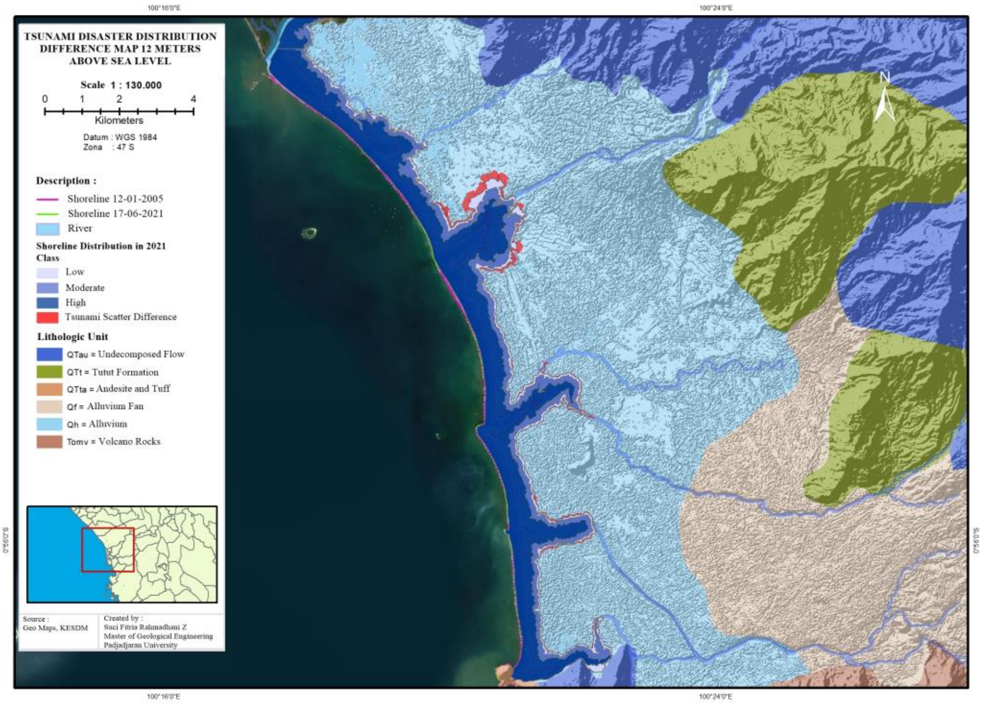


Figure 10 - Difference in Tsunami Landfall Zones of 12 meters above sea level at 2005 and 2021 coastlines

While the accretion event on the coastline of Padang city caused 48 observation points with an average of about 14.81 metres causing a tsunami landfall change of 12 metres about 22.91 metres back towards the sea. Points that affect the change in the landfall zone are 18 points in Koto Tangah sub-district, 12 points in North Padang sub-district and 18 points in West Padang sub-district.

The area in red is the difference in the area affected by the coastline in 2005 and 2021, by calculating and analysing using multivariate regression on the coastline variables in the form of abrasion and accretion events on coastline changes at a tsunami landfall of 12 metres above sea level.

Based on the R Square value of 0.122, it indicates that the effect of variables X1 and X2 together on variable Y is 12.2%. This explains that the geology of the observation area has a significant effect on the tsunami landfall zone of 12 metres above sea level by only about 12.2%. There is a change in the overall land area, namely a reduction in the tsunami disaster land area of 91.51995 hectares from 2005 to 2021 due to accretion events.

Conclusions

Changes in the coastline over time prove that the coastline changes and is always dynamic. This is evidenced by abrasion and accretion events occurring on the coast of Padang City from 2005 to 2021, with a total of 64 accretion events with an average distance of +13.06 metres and 58 points of abrasion events with an average distance of -17.06 metres at the measurement point. Changes in distance due to abrasion and accretion events that occur on the coast of Padang City are caused by natural factors such as waves, tides, currents, climate, river mouths and human activities around the coastal area.

The calculation of tsunami landfall zones using the coastline from 2005 to 2021 with tsunami modelling of 5 and 12 metres above sea level resulted in the following areas; the prediction of tsunami landfall zones of 5 metres above sea level is expected to hit five sub-districts including South Padang, West Padang, North Padang, Nanggalo and Koto Tangah. With an estimated tsunami wave travel distance of 145 to 1,743 metres inland.

The tsunami landfall zone of 12 metres above sea level is expected to hit five sub-districts, including South Padang, East Padang, West Padang, North Padang, Nanggalo and Koto Tangah. With an estimated tsunami wave travel distance of 525 to 2,703 metres inland. This indicates that there is a reduction or shrinkage of the tsunami landfall area of 5 metres above sea level, which is approximately 78.69 hectares, due to accretion events. Previous calculations also show that there is a reduction or shrinkage of the tsunami land area 12 metres above sea level, which is approximately 91.52 hectares due to accretion.

Conflicts of interest. On behalf of all authors, the corresponding author states that there is no conflict of interest.

CRediT author statement: **F. Suci**: Conceptualization, Methodology, Software Data curation, Writing draft preparation Visualization, Investigation; **Y. Teuku, E. Cipta:** Supervision.

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Паданг қаласы, Батыс Суматра, Индонезия: жағалаулық геоморфологиялық динамика және цунами қаупі бар аймақтар (теңіз деңгейінен 5–12 м жоғары)

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ТҮЙІНДЕМЕ
Паданг қаласы - Суматра аралының батыс бөлігіндегі астаналық қалалардың бірі, жалпы жағалау сызығының ұзындығы шамамен 68 126 км және Үнді мұхитына тікелей іргелес. Соңғы рет Батыс Суматра провинциясы 2009 және 2010 жылдары цунамиге ұшырады, ол 7,9 баллдық жер сілкінісі салдарынан биіктігі <1 метрден >12 метрге дейінгі цунамиді тудырды. Сарапшылар Ментавай аралдарының бойындағы мегатруст плиталарының жарылуынан туындаған жер сілкінісі апаттарының ықтималдығын бағалайды. Ерте және оңтайлы жұмсарту әрекеттері цунами апаттарын барынша азайтуға мүмкіндік береді. Бұл зерттеудің мақсаты теңіз деңгейінен 5 және 12 м биіктіктегі цунами таралу аймақтарына жағалау сызығының өзгеру әсеріне шолу жасау болып табылады. Бұл зерттеуде ArcGIS бағдарламалық жасақтамасындағы Географиялық ақпараттық жүйе арқылы өңделетін

Google Earth, әкімшілік, еңіс және жер жамылғысы туралы алынған 2005-2021 жылдардағы Паданг қаласының жағалау сызығының параметрлері пайдаланылады. Зерттеуде қолданылатын әдіс цунами тасқынының биіктігін төмен, орташа және жоғары деп үш шкалаға бөлу арқылы алынатын цунами тасқыны болып табылады. Зерттелетін аумақтың жағалау сызығының 18520 метрі бойында орналасқан 122 бақылау пунктінде бақылау жүргізілді. Нәтижелер Паданг қаласында теңіз деңгейінен 5 және 12 метр биіктіктегі цунами апаттарынан зардап шеккен бес-алты шағын аудан бар екенін көрсетеді, соның ішінде Оңтүстік Паданг, Шығыс Паданг, Батыс Паданг, Солтүстік Паданг, Нанггало, Кото Тангах. 2005 жылдан 2021 жылға дейінгі жағалау сызығының айырмашылығы бақылау аймағының жағалау сызығында болып жатқан аккрециялық құбылыстардан туындаған әрбір су деңгейінде шамамен 78,69-дан 91,51 гектарға дейін цунами таралу аймағының өзгеретінін көрсетеді.

Түйін сөздер: Жағалау сызығы, жер сілкінісі, цунами, апат салдарын азайту.

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АННОТАЦИЯ

Город Паданг — одна из столиц в западной части острова Суматра с общей протяженностью береговой линии около 68 126 км, непосредственно прилегающая к Индийскому океану. В последний раз провинция Западная Суматра пострадала от цунами в 2009 и 2010 годах, что вызвало цунами высотой от <1 метра до >12 метров, вызванное землетрясением магнитудой 7,9. Эксперты оценивают потенциальные катастрофы от землетрясений, возникающих из-за мега-разрывов плит вдоль островов Ментавай. Ранние и оптимальные усилия по смягчению последствий способны минимизировать последствия, вызванные катастрофами, вызванными цунами. Целью данного исследования является предоставление обзора влияния изменений береговой линии на зоны распространения цунами высотой 5 и 12 метров над уровнем моря. В этом исследовании используются параметры береговой линии города Паданг в 2005-2021 годах, полученные из Google Earth, администрации, уклона и земельного покрова, которые будут обработаны с использованием Географической информационной системы в программном обеспечении ArcGIS. Метод, используемый в исследовании, - затопление цунами путем деления высоты затопления цунами на три шкалы, включая низкую, среднюю и высокую. Наблюдения проводились в 122 точках наблюдения, разбросанных вдоль 18 520 метров береговой линии исследуемой области. Результаты показывают, что в городе Паданг есть от пяти до шести подрайонов, которые пострадали от цунами высотой 5 и 12 метров над уровнем моря, включая подрайоны Южный Паданг, Восточный Паданг, Западный Паданг, Северный Паданг, Нанггало, Кото Тангах. Разница в береговой линии с 2005 по 2021 год показывает изменение площади зоны распространения цунами примерно на 78,69–91,51 гектара на каждом уровне воды, вызванное аккреционными явлениями, происходящими вдоль береговой линии зоны наблюдения.

Ключевые слова: Береговая линия, землетрясение, цунами, ликвидация последствий стихийных бедствий.

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