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MORALITY BEFORE KNOWLEDGE

The impact of climate change on potential rob floods and its effect on regional spatial planning on the Surabaya coast

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ABSTRACT

Climate change is a global issue that is of concern to the world. One of the impacts of climate change is sea level rise. Rising sea levels can cause tidal floods, especially in coastal areas. Based on data from the Meteorology, Climatology and Geophysics Agency (BMKG), one evidence of climate change is an increase in sea level. Satellite altimetry measurements show a trend of sea level rise in Indonesia from 1992-2022 averaging around 4 mm/year. Rising sea levels have an impact on increasing the frequency of coastal flooding, retreating coastlines, and the disappearance of national borders. The city of Surabaya is one of the coastal cities in Indonesia which has the potential to experience an increase in the height of tidal floods due to climate change. The potential for tidal floods due to climate change could harm the spatial planning of coastal areas in Surabaya. The results of this research show that the coast of Surabaya has a moderate level of tidal flood vulnerability with an area of 8230.77 ha, a high category with an area of 1739.21 ha, and a very high category with an area of 178.13 ha. The area is dominant from most of the coast of the Semampir subdistrict to Benowo and the border of the Bulak and Mulyorejo subdistricts. Tidal floods can cause the submergence of productive lands, such as settlements, fish farms, and warehouses. This can cause economic and social losses for coastal communities. Therefore, adaptation efforts are needed to reduce the impact of tidal floods due to climate change. These adaptation efforts can be carried out through improving spatial planning and environmental planning for coastal areas.

Keywords: climate change; regional spatial planning; Surabaya; tidal floods

1. Introduction

Global warming is a global problem. The consequences of global warming are climate changes on Earth. There are several impacts of climate change, including rising sea levels, which if they continue to increase will cause parts of the land to become inundated (Wirasatriya et al, 2008). The rise in sea level has the potential to cause tidal flood disasters, where seawater will enter the land and will cause tidal floods in various areas. Coastline changes will also occur. This is characterized by the retreat of the coastline from its original position which is then defined as abrasion (Maurizka and Adiwibowo, 2021).

According to Saputra et al (2017) the city of Surabaya has coastal and water areas that have sufficient potential for development. The large number of shipping activities in

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Surabaya waters requires information about the dynamic conditions of the waters to ensure shipping security and safety. Triana and Hidayah (2020) said that the Surabaya coastal area is a coastal area that is affected by rising sea levels. The risk of tidal floods in this area is also supported by the topography of the city of Surabaya which is dominated by lowlands. The city of Surabaya consists of 80.72% or around 26,345.19 Ha of area with a height of 0-10 meters above sea level. Therefore, if tidal flooding occurs in this area, community activities could be disrupted and even stopped.

Tidal flooding (tidal flooding) is a pattern of sea level fluctuations that are influenced by the gravitational force of celestial bodies, especially the moon, and sun, on the mass (specific gravity) of seawater on Earth. Tidal floods include flood disasters caused by the entry of seawater onto land as a result of high tides. Rob directly occurs in areas on the coast where the highest sea tides enter the land and are blocked by barriers or physical buildings. Rob occurs when high tides inundate land that is lower than sea level at the highest tide. Tidal floods in coastal areas will get worse with the supply of rainwater or direct floods and local floods due to poorly maintained drainage channels. Sea water enters the drainage system at the highest tide and then breaks through the poorly maintained embankment onto land and inundates the area. Tidal floods pose a serious threat, namely abrasion of the shoreline, causing the shoreline basin to sink deeper into the land. Tidal floods cause changes in land use to become narrower or even disappear due to being submerged by tidal floods (Ikhsyan et al, 2017).

According to Desmawan and Sukamdi (2012), the impact of tidal floods is disruption of daily activities including household activities, disruption of road accessibility, and limited use of facilities and infrastructure. The impact of the tidal flood caused coastal infrastructure to be damaged due to coastal abrasion. As a result, coastal residents will lose their homes and livelihoods. Factors that cause tidal floods include sea level rise and land subsidence, apart from that, there are also factors such as the height of the land area and the existing drainage system that can also influence the existence of tidal floods. Factors causing tidal floods include tides, high rainfall, regional geography, and climate change. Besides that, tidal floods can also be caused by other factors or *external forces* such as the push of sea waves, storm surges, *and* tropical storms, which are phenomena that often occur at sea. The combination or interaction of all of these causes sea level anomalies which cause tidal floods (Jamalludin et al., 2016).

Areas far from the coastline can also be affected by tidal floods due to overflowing rivers. One of the causes of increasing river water discharge is rainfall. So analysis of rainfall levels in an area is very important because it can increase an area's vulnerability to tidal floods (Pyanto et al*.,* 2021).

Elevation is a criterion that is no less important. The characteristics of tidal floods will inundate areas with elevations lower than the tide level. Apart from that, distance from the river and distance from the coastline can also influence the formation of tidal floods (Saputra et al., 2020).

The Coastal Part of the Surabaya City Regional Spatial Plan Based on Surabaya City Regional Regulation Number 12 of 2014, which is currently being reviewed to be revised from the 2014-2034 period to the 2023-2043 period, which it determines the coastal area of the City of Surabaya as a strategic urban area. This coastal area has an area of around 1,231.50 hectares and covers the districts of Gunung Anyar, Kenjeran, Bulak, Asemrowo, Sukolilo, Benowo to Pakal.

The coastal area of Surabaya City has great potential for economic and tourism development. However, this area is also vulnerable to natural disasters, such as tidal floods and abrasion. To create sustainable, competitive, and sustainable coastal areas, the Surabaya City Government has established several policies, including:

1. Development of industrial and logistics areas, tourist areas, residential areas, and agricultural areas by paying attention to environmental aspects and natural sustainability.
2. Increasing water capacity on land, improving flood management infrastructure, relocating communities and public facilities, as well as changing spatial functions to reduce the risk of flooding and increase the resilience of coastal areas to natural disasters.

The development of the coastal area of Surabaya City will be carried out in stages by paying attention to environmental aspects and natural sustainability.

2. Methods

This research was conducted on the north coast of Surabaya starting from Pakal District to Gununganyar District (Figure 1). The data used in this research are listed in Table 1.

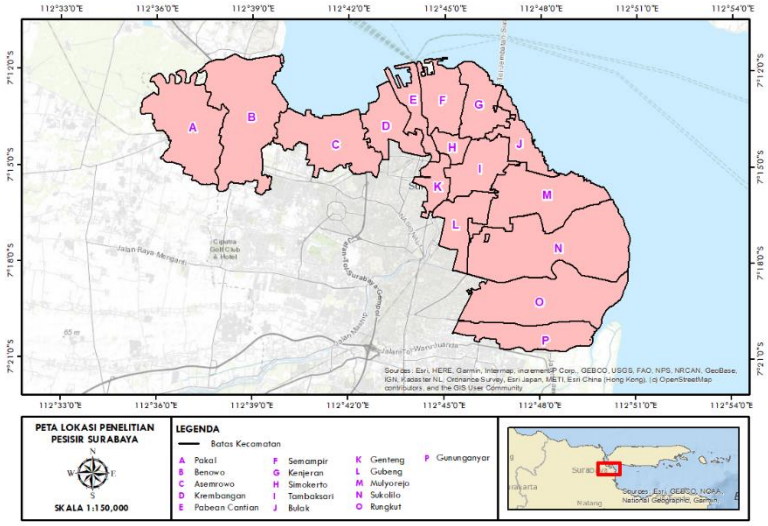

Figure 1. Map of research location

Table 1. Data used in research

No.	Data Requirements	Data source
1	Rainfall	BMKG data
2	Coastline *shapefile*	RBI map per region
3	River *Shapefile*	RBI map per region
4	Topography	DEMNAS

The data processing method used in this research uses an *overlay* and *scoring method* based on Geographic Information Systems (GIS). GIS is a system designed to capture, store, manipulate, analyze, organize, and display all types of geographic data (Irwansyah, 2013).

a. *overlay* method is an overlay method *used* to combine several maps containing information or data to produce a zoning of the level of physical vulnerability.
b. *scoring* method is the assignment of a score and weight to each parameter which is calculated based on its influence on the level of vulnerability. The score given to measure the level of physical vulnerability is 1-5, the greater the score and weight given, the higher the influence.

In determining the weight to measure the level of vulnerability, it is based on which factors have more influence on tidal floods (Fauzi et al., 2022). The tools used _ namely a Laptop, Ms. Word, Ms. Excel, and ArcGIS. ArcGIS is A *software* developed by ESRI (*Environment Science & Research Institute*) where meaning is compilation functions from various types different GIS *software* such as desktop GIS, server, and based GIS *websites* (Setyawan et al, 2018). Determination of *scoring* and weighting is listed in tables 3 to 6.

Table 2. Distance score criteria from the coastline

Parameter	Indicator	Score	Weight
Distance from Coastline (m)	> 1000 m	1	30%
	750 – 1000 m	2	
	500 – 750 m	3	
	250 – 500 m	4	
	0 – 250 m	5	

Source: (Ramadhany et al ., 2021) with modifications

Table 3. Score Criteria for Distance from River

Parameter	Indicator	Score	Weight
Distance from River (m)	> 400m	1	20%
	300 – 400 m	2	
	200 – 300 m	3	
	100 – 200 m	4	
	0 – 100m	5	

Source: (Ramadhany et al ., 2021) with modifications

Table 4. Topography score criteria

Parameter	Indicator	Score	Weight
Topography (m)	11 – 28 m	1	30%
	6 – 11 m	2	
	3 – 6 m	3	
	0 – 3 m	4	
	-5 – 0 m	5	

Table 5. Rainfall score criteria

Parameter	Indicator	Score	Weight
Total Rainfall (mm/year)	< 1500	1	20%
	1501 – 2000	2	
	2001 – 2500	3	
	2501 – 3000	4	
	> 3000	5	

Source: (Fauzi , 2022) with modifications

3. Results and Discussion

3.1 Analysis of spatial results

The city of Surabaya is one of the cities in East Java which has an area of 33,440 ha with 31 sub-districts. The 16 sub-districts are close to the sea, namely the sub-districts of Pakal, Benowo, Asemrowo, Krembangan, Pabean Cantian, Semampir, Kenjeran, Simokerto, Tambaksari, Bulak, Genteng, Gubeng, Mulyorejo, Sukolilo, Rungkut, and Gununganyar. The Surabaya coastal area is a coastal area that is affected by rising sea levels which can cause tidal floods. In simple terms, flooding is the inundation of land by water in excess volume (not by its capacity). Floods can be caused by two factors, namely human factors and natural factors. Human factors are based on spatial planning and human activities themselves on the condition of sewers and flood drainage channels. Natural factors are influenced by topography, soil type, land use, and rainfall. In this research, mapping of coastal areas that are vulnerable to tidal floods was carried out using parameters such as topography, rainfall, distance from land to rivers, and distance from the coastline. With mapping, the government can take appropriate policies to address and overcome it.

Based on the elevation map which has been processed using ArcGIS *software*, it can be seen that the elevation in the coastal area of Surabaya City ranges from -5 to 28 meters. Most

of the coastal areas of Surabaya City which are directly adjacent to the ocean have a very low elevation, namely -5 to 0 meters compared to areas in the center of the city with a percentage of 28.27%. This is following Suprijanto's statement (2003), that the city of Surabaya is divided into two topographic areas, namely lowlands and undulating plains, with 80.72% composed of lowlands. Most of the lowland areas are at elevations below the highest tide with the highest tide in December 2022 in the northern part reaching 184.3 cm and in the eastern part reaching 172.7 cm. The low elevation of the coastal areas of Surabaya City, which has a lower elevation than the highest tide or the same as MSL, is an indication of tidal flooding. Where the main cause of tidal floods is the land surface elevation which is not higher than the highest sea tide.

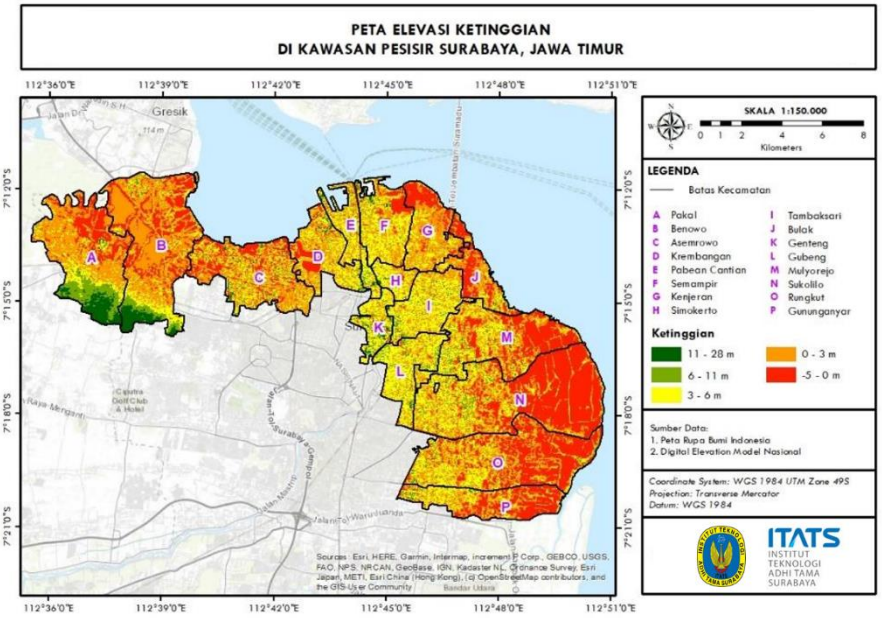

Figure 2. Elevation map in the surabaya coastal area

Tha area based on elevation in the Surabaya coastal area is more clearly listed in Table 6 below.

Table 6. Altitude elevation values in the surabaya coastal area

No	Ketinggian	Luas (Ha)	%
1	-5 - 0 m	5707.44	28.27
2	0 - 3 m	7362.05	36.47
3	3 - 6 m	5290.80	26.21
4	6 - 11 m	1400.19	6.94
5	11 - 28 m	428.41	2.12
Total		20188.9	100

Apart from land surface elevation, land distance from rivers is one of the variables calculated in determining the zoning level of physical vulnerability to tidal floods. Geographically, the city of Surabaya is downstream of the Brantas River Basin (DAS) which empties into the Madura Strait. The Surabaya River is one of two branches of the Brantas River. The Surabaya River originates in Mojokerto City and flows northeast across Surabaya City until it empties into the Madura Strait. As a downstream area, the city of Surabaya is an area where water overflows from passing rivers and can result in flooding during the rainy season. Apart from that, the presence of rivers in coastal areas during the rainy season can increase the vulnerability of these areas to tidal floods. Based on the map of land distance from river bodies, it can be seen that most coastal areas are far from river bodies. In areas

that are less than 400 meters from the river body, you must be careful because it can increase the vulnerability of the area to flooding. Tidal floods are not only caused by the overflow of tidal seawater, but these floods can occur due to overflowing river water. This could be due to the possibility of narrowing the width of the river or sedimentation of the river bed due to careless dumping of rubbish or due to the presence of a tidal prism in the river (Saputra et al., 2020).

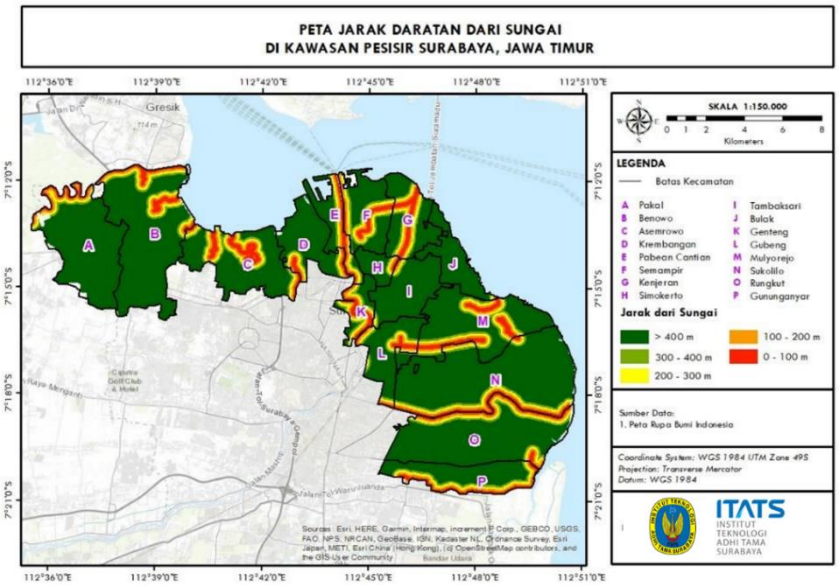

Figure 3. Map of distance from land to rivers in the Surabaya coastal area

The area based on land distance class from rivers in the Surabaya coastal area is more clearly listed in Table 7 below.

Table 7. Value of land distance from river in surabaya coastal area

No	Jarak dari sungai	Luas (Ha)	%
1	0 - 100 m	1978.13	5.899444
2	100 - 200 m	1678.72	5.006495
3	200 - 300 m	1667.40	4.972737
4	300 - 400 m	1646.95	4.911756
5	> 400 m	26559.64	79.20957
Total		33530.85	100

According to Ramdhany et al . (2021), distance from the coast is also a determining factor in identifying areas that are potentially threatened by tidal flooding. The coastline is the meeting point between land and sea which is influenced by tides and its condition will change from time to time. The coastline has a dynamic shape so it can cause continuous changes in shape. Changes in coastlines can be in the form of land reduction (abrasion) or land increase (accretion). Changes in coastlines in the form of land reduction or abrasion will have the impact of increasing an area's vulnerability to tidal floods. If an area is located close to the coastline, it can be identified that the area is vulnerable to tidal floods due to tidal runoff. Based on the map of land distance from the coastline which has been created using the scoring method, it can be seen that a distance of 0 – 250 meters from the coastline has a high vulnerability to tidal lines. This can happen because the closer an area is to the coast, the greater the high tides reaching that land area. In the city of Surabaya, the distance from the beach is > 1000 meters and has an area of 29326.67 ha so the area can be said to be safe from tidal floods.

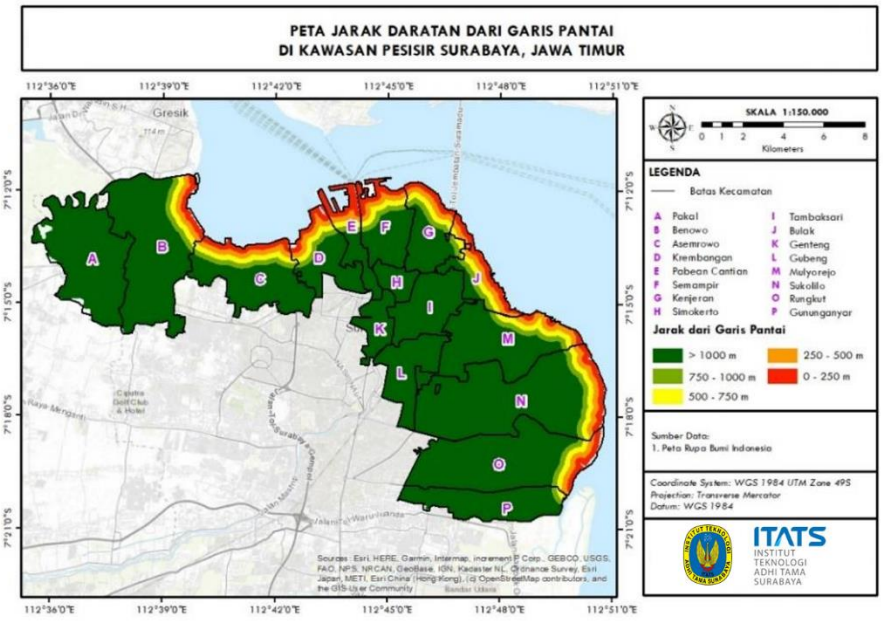

Figure 4. Map of land distance from the coastline in the surabaya coastal area

The area based on the land distance value from the coastline in the Surabaya coastal area is more clearly listed in Table 8 below.

Table 8. Value of land distance from the coastline in the surabaya coastal area

No	Jarak daratan dari garis pantai	Luas (Ha)	%
1	> 1000 m	29326.67	87.46
2	0 - 250 m	1344.45	4.01
3	250 - 500 m	988.13	2.95
4	500 - 750 m	943.36	2.81
5	750 - 1000 m	928.25	2.77
Total		33530.8	100

According to Jannah and Rohmatun (2018), tidal floods are floods that occur due to overflowing sea or river water which can be caused by excessive water overflowing in a place, one of which is due to high rainfall. Areas far from the coastline can also be affected by tidal floods due to overflowing rivers. One of the causes of increasing river water discharge is rainfall. So analysis of rainfall levels in an area is very important because it can increase an area's vulnerability to tidal floods. Based on the rainfall distribution map that has been created using data from two BMKG stations in Surabaya, it can be seen that most of the city of Surabaya during 2022 will have high rainfall intensity with rainfall amounts of 2501 to 3000 mm/year. With fairly high rainfall, the potential for tidal flooding on the coast of Surabaya City is relatively high.

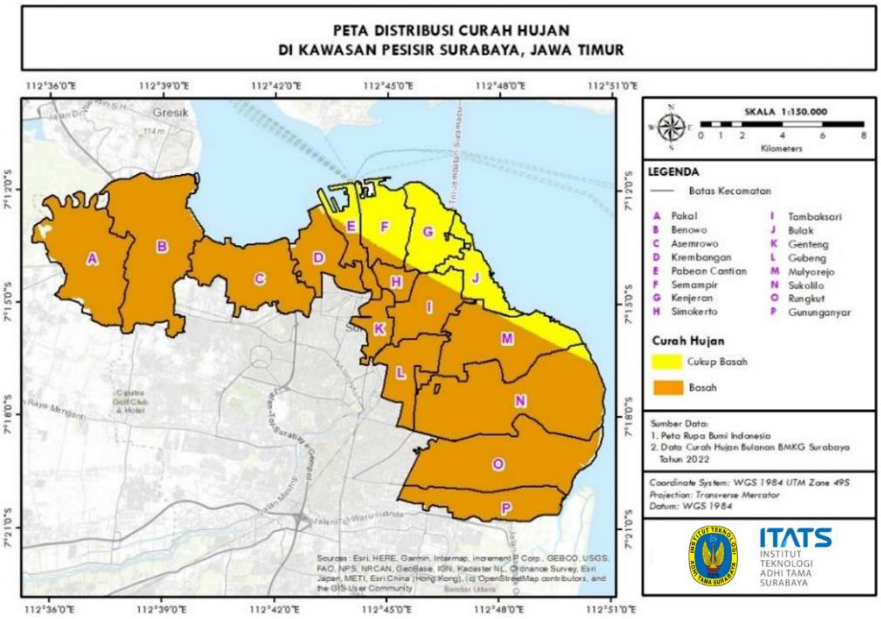

Figure 5. Rainfall distribution map in the surabaya coastal area

The area based on the rainfall intensity value in the Surabaya coastal area is more clearly listed in Table 9 below.

Table 9. Rainfall intensity values in the surabaya coastal area

No	Tingkat Kerawanan	Luas (Ha)	%
1	Cukup basah	3041.03	10.06
2	Basah	27173.05	89.94
Total		30214.08	100

Based on the parameters of land surface elevation, distance from rivers, distance from the coast, and rainfall, scoring, and *overlaying have been done* to produce a map of areas that are vulnerable to tidal flooding. The scoring for each parameter is different, namely the weight of the parameters for elevation, height of the land surface, and distance from the coastline is 30%, while the weight of the parameters for distance from rivers and rainfall is 20%. Determining the weights for each thematic map is based on subjective considerations based on certain considerations based on an understanding of the process, the possibility of flooding is influenced by each geographic parameter that has been determined and will be used in carrying out GIS analysis. After scoring and *overlaying*, a map of areas prone to tidal flooding is obtained. Based on the map of areas prone to tidal flooding, it can be seen that the vulnerability of coastal areas directly adjacent to the coast has a higher level of vulnerability than areas not directly adjacent to it with moderate to very high levels of vulnerability. Overall, the coastal area of Surabaya City which has a very low level of vulnerability has an area of 100.28 ha with a percentage of 0.5%, areas with a low level of vulnerability have an area of 9759.95 ha with a percentage of 48.78%, areas with a medium level of vulnerability have an area of 8230.77 ha with a percentage of 41.14%, areas with a high level of vulnerability have an area of 1739.21 ha with a percentage of 8.69%, and areas with a very high level of vulnerability have an area of 178.13 ha with a percentage of 0.89%. Areas that have a moderate to very high level of vulnerability can be caused by being close to coastlines and rivers, having land surface elevations that are less than or equal to MSL, and having high rainfall. Based on the map of areas prone to tidal floods, it can be seen that the Semampir to Benowo sub-districts have areas that are more vulnerable to tidal floods than other areas. This is following the statement by Triana and Hidayah (2020), who stated

that the Semampir to Benowo sub-districts have the potential to be inundated by tidal floods.

3.2 Analysis of robust flood prone areas on spatial planning and environmental planning on the coast of Surabaya

After reviewing the Surabaya Regional Spatial Planning (RTRW) for coastal areas for 2023-2043, the Surabaya City Government is trying to increase the competitiveness and welfare of Surabaya's coastal communities through developing the potential of coastal areas in a sustainable and environmentally sound manner. Regarding the potential for coastal flooding, including tidal floods, the government has made efforts to maximize the function of green space for water catchment areas, maximize drainage system management, and promote *mangrove planting* for coastal areas that are prone to coastal flooding. However, over time, the population of Surabaya's coastal residents has increased, so that settlements in Surabaya's coastal areas have become increasingly dense. On the other hand, climate change creates new problems that must be watched out for, because several tidal floods that have occurred on the coast of Surabaya have been in conditions beyond normal. This is of course due to sea levels increasing every year, also triggered by quite high rainfall, as well as poor awareness of waste and waste management which further worsens the existing conditions.

Quoting from the book "The City of Surabaya Towards a Disaster Resilient and Climate Change Resilient City" published by the Directorate General of Spatial Planning of the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency in 2016, the analysis of the risk of high tide/tidal flood disasters is assessed based on the KRB Flood Flood map from the RTRW Surabaya City, results of vulnerability analysis and capacity analysis results. According to Prasita and Kisnarti's research conducted in 2013, a picture was obtained if it was assumed that if there was a rise in sea level of 1 meter, the coastal areas in Surabaya that could potentially be directly affected were Romokalisari and Tambak Osowilangun (Benowo District), Tambak Langen, Greges, and Kalianget (Asemrowo District), Morokrembangan and West Perak (Krembangan District), North Perak and East Perak (Pabean Cantikan District), Kedung Cowek (Kenjeran District), Sutorejo Hamlet, Kalisari, and Kejawen Putih Tambak (Mulyorejo District), Keputih (Sukolilo District), Medokan Ayu, and Wonorejo (Rungkut District), Gunung Anyar Tambak (Gunung Anyar District).

Prawira and Pamungkas (2014) stated that there are 11 vulnerability factors related to tidal flood mitigation in the northern coastal area of Surabaya, namely high building density, condition of the road network inundated by tidal floods, less than optimal condition of drainage channels, residential areas in the lowlands, facilities general areas are inundated by tidal floods, high population density, decreased income of people in vulnerable sectors, reduced water catchment areas, reduced mangrove forest areas, residential areas are in the lowlands and built-up areas are built on former swamp land. Based on vulnerability factors, the formulation given by Prawira and Pamungkas (2014) in efforts to mitigate areas prone to tidal flooding in the North Coast Area of Surabaya is building embankments and sluice gates, building pump houses, providing a stilt house concept, developing mangrove forest areas, arranging buildings in around the coast, the formation of government and non-government organizations related to disasters, the provision of hazard and risk maps of sea level rise and the provision of disaster-friendly spatial planning concepts.

Based on the results of the spatial analysis in this research, it can be seen that the Surabaya coastal area has a fairly high level of vulnerability to tidal floods. Therefore, policies and strategies in the Surabaya RTRW for the coast need to be focused again on the Surabaya coastal area. This is important to do so that appropriate mitigation steps can be taken if conditions change in the coastal areas of Surabaya.

4. Conclusion

Based on the research that has been carried out, several conclusions can be drawn:

a. Based on the land surface elevation map, distance from the river, distance from the coastline, and rainfall, it can be seen that the land surface elevation on the coast of Surabaya City ranges from -5 to 28 meters, most of the land distance from the river is > 400 meters, most The distance from the coastline is > 1000 meters, and most of the coast of Surabaya City has an amount of wet rainfall with an intensity of 2001 to 2500 mm/year.
b. Judging from the four parameters used as well as the scoring and overlay results, it can be seen that the coast of Surabaya City has moderate to very high vulnerability. Areas that have a moderate level of vulnerability are dominantly on the east coast of Surabaya City, while areas that have high to very high vulnerability are predominantly on the north coast of Surabaya City.
c. By mapping areas prone to tidal flooding, it can be used as a government archive to be used as consideration in making policies and decisions regarding Spatial Planning and Environmental Planning for the City of Surabaya, especially coastal areas.

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Author Contribution

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study

Data Availability Statement

Not applicable

Conflicts of Interest

The authors declare no conflict of interest

Reference

Al Fauzi, R. (2022). Analisis tingkat kerawanan banjir Kota Bogor menggunakan metode overlay dan scoring berbasis sistem informasi geografis. *Geo Media: Majalah Ilmiah dan Informasi Kegeografian*, *20*(2), 96-107. http://dx.doi.org/10.21831/gm.v20i2.48017

Desmawan, B. T., & Sukamdi, S. (2012). Adaptasi masyarakat kawasan pesisir Terhadap banjir rob di kecamatan sayung, Kabupaten demak, jawa tengah. *Jurnal Bumi Indonesia*, *1*(1). https://www.academia.edu/download/32447975/38-75-1-SM.pdf

Directorate General of Spatial Planning, Ministry of Agrarian Affairs and Spatial Planning. (2016). Surabaya City Towards a Disaster Resilient and Climate Change Resilient City. National Land Agency, Jakarta. 110 p. http://eprints.itn.ac.id/5048/1/Buku-4%20Kota%20Surabaya%20Menuju%20Kota%20Tangguh%20Bencana%20dan%20Berketahanan%20Iklim_reduceOK.pdf

Ikhsyan, N., Muryani, C. and Rintayati, P., 2017. Analysis of the Distribution, Impact and Community Adaptation to Rob Floods in East Semarang District and Gayamsari District, Semarang City. *GeoEco* , *3* (2), 145-156. https://jurnal.uns.ac.id/GeoEco/article/view/14310/11894

Irwansyah, E. 2013. Geographic Information Systems: Basic Principles and Application Development. Digibooks printing and publishing, Yogyakarta. 221 pp . https://books.google.co.id/books?id=sH06bnsuStcC&printsec=frontcover

Jannah, SN, and Rohmatun . 2018. The Relationship Between Social Support and Resilience in Rob Tambak Lorok Flood Survivors. *Projections* , 13(1): 1-12. http://dx.doi.org/10.30659/jp.13.1.1-12

Maurizka, IS, & Adiwibowo, S. (2021). Fishermen's Adaptation Strategy to Face the Impact of Climate Change. *Journal of Communication Science and Community Development [JSKPM]* , *5* (4), 496-508. https://doi.org/10.29244/jskpm.v5i4.866

Prasita, VD, Kisnarti, EA 2013. Prediction Of Sea Level Rise Impacts On The Coastal Areas Of Surabaya Using GIS. *The International Journal Of Engineering And Science (IJES)* , 2(7):01-09. http://dspace.hangtuah.ac.id:8080/xmlui/bitstream/handle/123456789/210/A02750109.pdf?sequence=1

Prawira , MP, Pamungkas , A. 2014. Mitigation of Robust Flood Prone Areas in the North Coast Area of Surabaya. *POMITS ENGINEERING JOURNAL*, 3(2). http://dx.doi.org/10.12962/j23373539.v3i2.7252

Pyanto , F., Mulia, AP, & Surbakti , MS 2021. Robust Flood Mapping in the North Medan Region Using Logistic Regression and GIS. *Literate Syntax; Indonesian Scientific Journal* , *6* (9), 4436-4454. https://doi.org/10.36418/syntax-literate.v6i9.1579

Ramdhany, AD, Wiranegara, HW, and Luru, MN, 2021. Zoning of Physical Vulnerability Levels for Rob Floods in Tugu District in Semarang City. *Bhuwana Journal* , 1 (2): 137-146. https://doi.org/10.25105/bhuwana.v1i2.12532

Saputra, NA, Tarigan, APM and Nusa, AB 2020. Use of AHP and GIS Methods for Zoning Areas Prone to Robo Floods in the North Medan Region. *Civil Engineering Communication Media* , *26* (1): 73-82. https://doi.org/10.14710/mkts.v26i1.26211

Saputra, VH, Rifai, A., and Kunarso., 2017. Seasonal Variability of Current Patterns in the Waters of Surabaya, East Java. *Journal of Oceanography* , 6(3):439-448. https://ejournal3.undip.ac.id/index.php/joce/article/view/20203/19058

Setyawan, D., Nugraha, AL, and Sudarsono, B., 2018. Analysis of Village Potential Based on Geographic Information Systems. *Undip Geodesy Journal* , 7(4):1-7. https://doi.org/10.14710/jgundip.2018.22401

Suprijanto, I., 2003. Vulnerability of Waterfront Areas to Sea Level Rise, Case of Waterfront Areas in the City of Surabaya. *Dimensions of Architectural Engineering* , 31(1): 28-37. https://doi.org/10.9744/dimensi.31.1.

Triana, YT and Hidayah, Z., 2020. Study of Potential Areas Prone to Rob Floods and Community Adaptation in the North Coastal Area of Surabaya. *Juvenile, 1*(1):141-150. https://doi.org/10.21107/juvenil.v1i1.6961

Wirasatriya A, Hartoko A, and Suripin. 2006. Study of Sea Level Rise as a Foundation for Flood Management on the Coast of Semarang City. *Sea Sand Journal, 1*(2), 31-42. http://eprints.undip.ac.id/4155/1/1b-Anindya.pdf

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