p-ISSN 2460-0768 e-ISSN 2597-6044
GeoEco, Vol. 12, No 2. July 2026 Page. 935 - 954
https://doi.org/10.20961/ge.v12i2.115215
https://jurnal.uns.ac.id/GeoEco/article/view/115215

TIDAL FLOOD DISASTER ADAPTATION AND MITIGATION BASED ON GEOSPATIAL ANALYSIS IN PEMANGKAT SUB-DISTRICT, WEST KALIMANTAN

Ajun Purwanto[1]*, Sulha[2]
[1]Department of Geographic Information Science, PGRI Pontianak University, Pontianak, Indonesia
[2]Department of Citizenship Education, PGRI Pontianak University, Pontianak, Indonesia
*E-mail: ajunpurwanto@gmail.com

ARTICLE INFO

Article History
Received : 27/01/2026
Revised : 19/06/2026
Accepted : 15/07/2026

Citation:
Purwanto, A., and Sulha, S. (2026) Tidal Flood Disaster Adaptation and Mitigation Based on Geospatial Analysis in Pemangkat Sub-District, West Kalimantan. GeoEco. Vol. 12, No. 2.

ABSTRACT

Tidal flooding is a recurring disaster in Indonesia, including West Kalimantan. This study aims to analyze the spatial distribution of tidal flood vulnerability and identify appropriate mitigation and adaptation strategies in Pemangkat District, Sambas Regency. This study uses a combination of field surveys and secondary data analysis. The variables used include elevation, slope, distance from rivers, land cover, and rainfall. Spatial analysis uses a Geographic Information System (GIS) with the Weighted Sum method to generate a tidal flood vulnerability map. The results show that tidal flood vulnerability in the study area can be classified into five categories: very low, low, moderate, high, and very high. High to very high vulnerability zones are mostly located in Pemangkat Kota and Sebatuan villages, while moderate to very low vulnerability zones are found in Jelutung, Gugah Sejahtera, Penjajap, Harapan, Lonam, and Parit Pakan villages. Model validation shows an overall accuracy of 58%, with Producer Accuracy and User Accuracy reaching 85%, indicating a good match between the generated vulnerability map and historical tidal flood events. Findings indicate that low-lying coastal areas affected by tidal channels are most vulnerable to tidal flooding. Priority adaptation strategies include the construction of permanent embankments, adaptive spatial planning through the utilization of flood-prone zones for fish farming, and the relocation of settlements from high-risk areas. Recommended mitigation measures for moderate to low vulnerability zones include the construction of stilt houses, improving drainage systems, installing water pumps, developing infiltration ponds, and restoring mangrove forests.

Keywords: *adaptation; geospatial analysis; mitigation; tidal flood*

INTRODUCTION

Landforms have a vital part in examining flooding since landforms could be a cross-sectional shape for the method of streaming water to the ocean. Flooding happens the most in places that are flat or gentle. This can indicate that flood-prone landscapes include floodplains, beaches, swamps, and backwaters. The geomorphological characteristics of flood areas are characterized by morphology in the form of depressions or flat relief landforms related to streams. Some rivers twist and turn a lot, and these areas could be places where water might overflow and cause floods (Pourali et al., 2018; Riadi, 2018).

Flooding may be an issue for a nation and has indeed become a worldwide issue in different nations. Floods are a natural disaster that causes a lot of damage and is a phenomenon that often occurs in villages and city areas in coastal areas. Floods cause losses in the form of monetary and population losses (Li et al., 2020a; Sayama et al., 2015) and social, economic, and educational losses.

Globally, the frequency of coastal flooding has increased significantly by more than 50% in the last two decades due to global average sea level rise. Research by Vitousek et al. (2017) suggests that a projected sea level rise of 10–20 cm in the last two decades before 2050 could more than double the frequency of extreme coastal flooding, particularly in tropical regions (Almar et al., 2021; Vitousek et al., 2017).

Several coastal cities in Indonesia, such as Jakarta, Semarang, Pekalongan, Demak, Indramayu, and coastal areas of Kalimantan, have experienced an increase in tidal flooding in recent decades. In many coastal areas, tidal flooding no longer occurs only during peak tides but has become a seasonal or even annual phenomenon, disrupting socio-economic activities (Putiamini et al., 2023).

Coastal areas, which are transitional zones between land and sea, have abundant natural resources (Hamuna et al., 2018). They also have a strategic role due to their economic value, ecological value, and high zone productivity (K. K. Ahmad et al., 2021). Various other aspects, not only related to the economy, but also the utilization of coastal resources to meet the needs and development in related areas, are also available (T. E. Ahmad et al., 2021).

However, it is not uncommon for these potentials to shrink, along with the level of vulnerability of coastal areas to environmental changes that can cause natural disasters (Lestari et al., 2021). In the form of floods, hurricanes, volcanic eruptions, earthquakes, tsunamis, and so on. The level of damage caused by disasters depends on the level of community resilience to the risks posed.

Currently, flood risk analysis is mostly done by focusing on spatial aspects, which include the location and extent of flooding. The components used as the basis for identifying or assessing flood risk are determined by figuring out three, specifically, danger, and flood publicity. Spatial information, risk, and flood inundation predictions are important and can help us get ready and stay safe during floods and planning efforts, or in this case, it can be referred to as adaptation. The risks and impacts of flooding will be easier to understand if there is spatial information on flooding (Singh et al., 2017; Yildirim & Demir, 2021) as well as planning and mitigation as well as adaptation. Prioritizing providing assistance and mitigating damage will be easier if there is accurate information (Purwanto & Paiman, 2023; Rosser et al., 2017). Floods are caused by many factors, such as high precipitation, surface runoff, drainage flows that are no longer able to accommodate runoff, human actions in environmental management, and other issues that significantly influence flooding.

West Kalimantan, particularly the coastal areas of Sambas Regency and Pemangkat District, is highly vulnerable due to low-lying topography, strong tidal influences, and the potential for future sea-level rise. Therefore, vulnerability mapping and coastal adaptation planning are crucial steps to reduce the risk of tidal flooding in the region (Vitousek et al., 2017)

Pemangkat sub-district is one of the sub-districts that has a fairly high risk of tidal flood. Pemangkat is an area located in the coastal zone. Tidal flood occurs due to changes in sea level, which are influenced by the gravitational pull of the moon and sun on the volume of seawater. Other factors that cause tidal flood include land degradation, poor drainage, land degradation, local hydrological conditions, and flat topography, land subsidence, sea level rise (Azhari et al., 2022), and climate change (Azhari et al., 2022; Iskandar et al., 2020). Therefore, tidal flood prediction has become very complex because it involves many variables that cause flooding (Xiang & Demir, 2020)) and tidal flood is no exception.

Spatial information about disasters and the impact of flooding, one of which is the existence of a flood risk map, includes flood risk maps, which are caused by tidal flood important resource to minimize the impact of flooding that can be included in the mitigation process. A flood risk map (Li et al., 2020b, 2020a; Sermet et al., 2020; H. Xu et al., 2020) and also adaptation processes.

Tidal flood mapping can be done by utilizing the current emerging technology, namely geospatial technology. This technology requires intensive computation, complex data, and the need for calibration from experts (Ramesh & Iqbal, 2022; Teng et al., 2017) and this sometimes becomes an obstacle in the mapping process. One spatial analysis that emphasizes tidal flood catastrophe is with the aid of using geospatial technology (Purwanto & Paiman, 2023).

Pemangkat District is one of the coastal areas of Sambas Regency that regularly experiences tidal flooding. In January 2023, hundreds of homes in Banjar Hamlet, Pemangkat Kota Village, were inundated for 2–3 hours. In a more severe incident in December 2025, almost all hamlets in Pemangkat Kota Village were inundated, with floodwaters reaching a depth of approximately one meter, disrupting community activities, government services, and educational activities. This situation indicates that the coastal area of Pemangkat is highly vulnerable to tidal flooding and requires spatial-based mitigation strategies to support future disaster risk management (BPBD, 2025; Pontianak Post, 2023).

Although several studies have examined flooding and tidal influences in Pemangkat District, geospatial-based tidal flood vulnerability mapping that integrates coastal physical factors is still lacking. Therefore, this study aims to address this gap by modeling tidal flood vulnerability using GIS and remote sensing approaches. This study aims to analyze the spatial distribution of tidal flood vulnerability and to identify appropriate mitigation and adaptation strategies in Pemangkat District, Sambas Regency.

MATERIALS AND METHODS

1. Study Area

The research area is in the Pemangkat sub-district, Sambas District. Pemangkat sub-district is astronomically located at 1080 54' 01" E - 1090 04' 49" E and 10 05' 01" N - 10 12' 14 N. Pemangkat District consists of 8 villages, namely Rapakan Besi, Pemangkat Kota, Harapan, Sungai Tomam, Serunai, Jlutung, Parit Baru, and Penjajap. The administrative area of the Pemangkat sub-district is 8,247.05 Ha. The region of the research area can be seen in **Figure 1**.

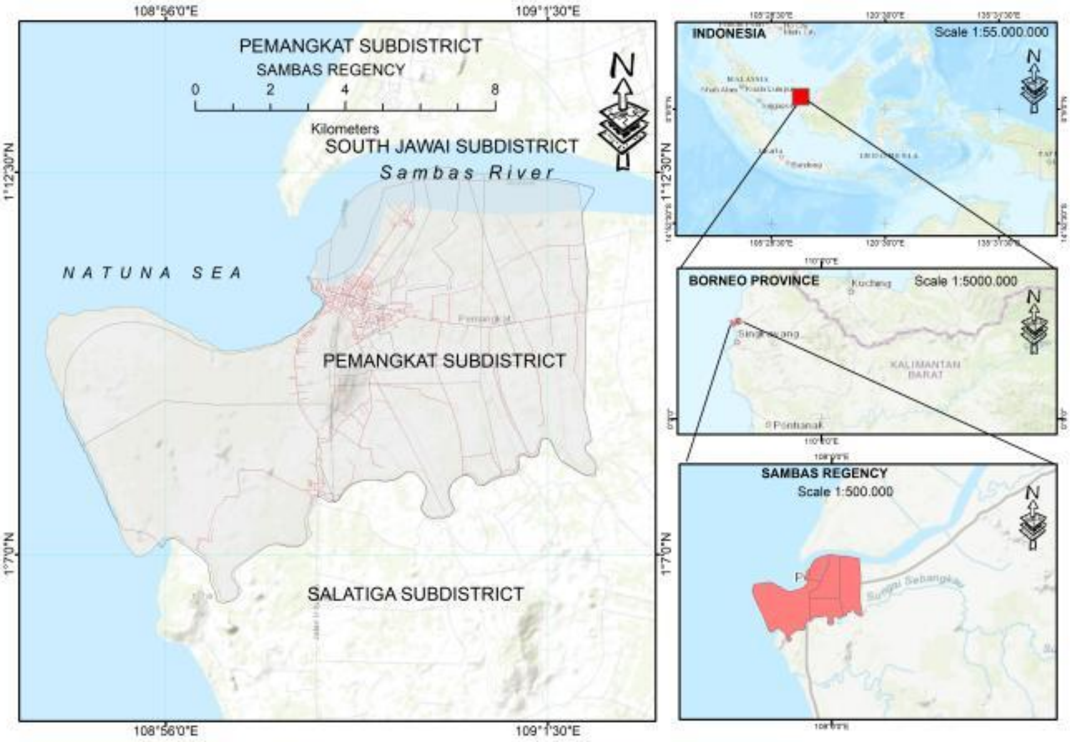

Figure 1. Study Area
Source: Administrative Map of Sambas Regency

2. Methods

Geospatial analysis in this study was used to predict and visualize the level of tidal flood vulnerability in the study area. This approach integrates various spatial and non-spatial data to identify areas potentially affected by tidal flooding. The spatial data used included thematic maps, topographic data, river networks, and satellite imagery, while non-spatial data included rainfall and the region's hydrological characteristics. Through geospatial analysis and modeling, each parameter was evaluated based on its influence on tidal flooding events, resulting in a vulnerability map depicting the level of risk at each location. The results of this analysis can be used as a basis for more effective mitigation, adaptation, and coastal area management planning.

The determination of tidal flood adaptation and mitigation strategies was carried out using the Spatial Multi-Criteria Decision Analysis (Spatial MCDA) approach. This method integrates the results of the tidal flood vulnerability map with technical, economic, environmental, and social criteria through Analytical Hierarchy Process (AHP) weighting. The analysis results were used to determine the most appropriate adaptation and mitigation measures for each vulnerability class, thus providing guidance for more effective and sustainable coastal area management. The factors of tidal flood vulnerability can be seen in **Table 1**.

Table 1. Factors used in the tidal flood vulnerabelity

Classification	Sub-Classifications	Data Source	Gis Data Type	Derivative Map
Inventory of flood events	Flood inventory	Regional Drinking Water Authority and Field survey	Primary and secondary	-
	Altitude	DEM	GRID	Altitude
DEM	Tilt angle	DEM	GRID	Tilt angle
	Distance from stream	DEM	Channel coverage	Distance to stream
Land cover type	Land cover	Sentinel-2	GRID	Land cover
Precipitation	Precipitation	CHIRPS 2025	GRID	Precipitation

Source: Secondary data analysis

Briefly, the flow diagram in the research can be seen in **Figure 2**.

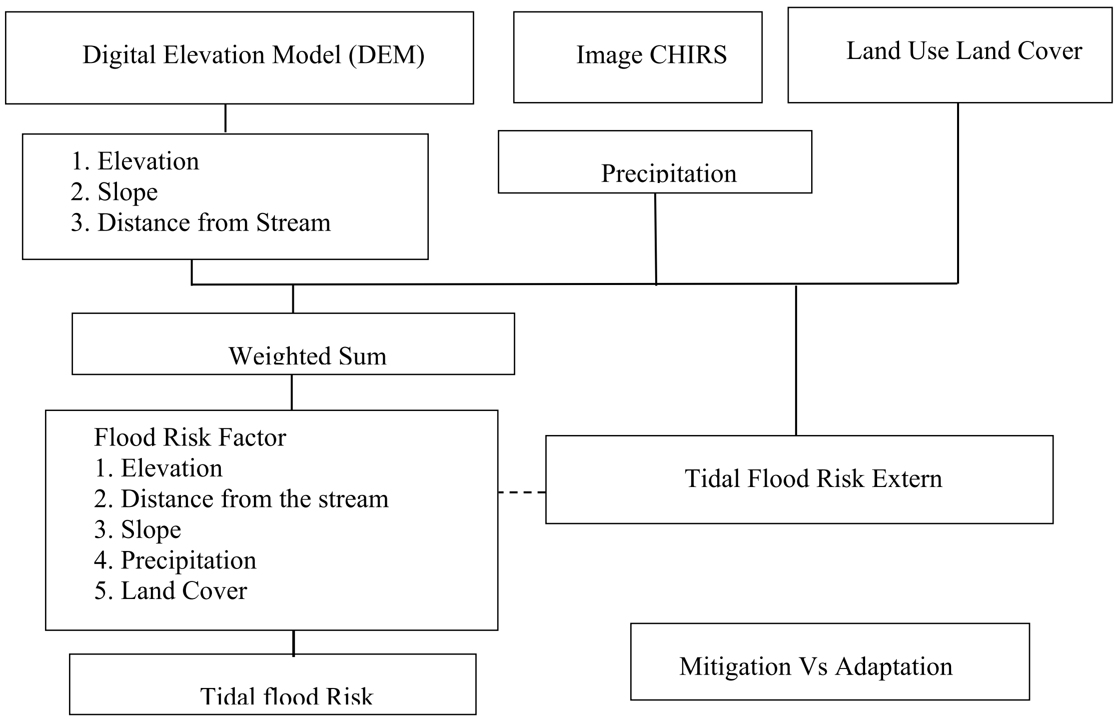

Figure 2. Flow Diagram
Source: Author's own elaboration (2026)

In summary, the weights of factors affecting tidal flood risk can be seen in **Table 2**.

Table 2. Tidal Food Vinerability Parameter and their Weights

Tidal Flood Vunerability	Descriptive	Ranking	Reclass	Influence (%)	Weighted
	Very low	10	16 - 59		
	Low	8	59 - 120		
Elevation (m)	Moderate	6	120 - 190	10	0.10
	High	4	190 - 274		
	Very High	2	274 - 403		
	Very low	10	0 - 2		
	Low	8	2 - 5		
Slope (%)	Moderate	6	5 - 10	15	0.15
	High	4	10 - 15		
	Very High	2	> 15		
	Very low	10	0 - 100		
	Low	8	100 - 200		
Distance from drainage (m)	Moderate	6	200 - 300	30	0.30
	High	4	300 - 400		
	Very High	2	> 400		
	Very low	10	> 2.620		
Precipitation (mm/h)	Low	8	2.590 - 2.620		
	Moderate	6	2.570 -2.590	35	0.35
	High	4	2.550 - 2.570		
	Very High	2	2.523 - 2.550		
	Very low	10	Waterbody		
	Low	8	Swam		
Land Cover	Moderate	6	Settlement	10	0.10
	High	4	Ricefield		

Source: Secunder data analysis and Analytical Hierarchy Process (AHP)

RESULTS AND DISCUSSION

1. Topographical Factors

Elevation is a significant factor in the occurrence of tidal flood. Tidal flood will increase as the altitude of a place decreases (Choubin et al., 2019; Mumbai, 2020). Areas located in every lowlands often experience tidal flood rainy season. The height and slope angle of the research site are divided into five classes (Heinzlef et al., 2020). The elevationof the research area can be seen in **Figure 3**.

Slope is an important parameter in the hydrological aspect. The slope is a function of the straight line ratio with surface runoff, so it can cause flooding (Mumbai, 2020). In general, low-lying areas have a flat to gentle slope, making them more susceptible to flooding and inundation. For flat to gentle slopes, runoff collects in one area and flows back at different times. Therefore, slopes with low slopes along the coast are more prone than slopes with high slopes. The resulting heights and slopes show very low spatial variations. The slope of the research area can be seen in **Figure 4**.

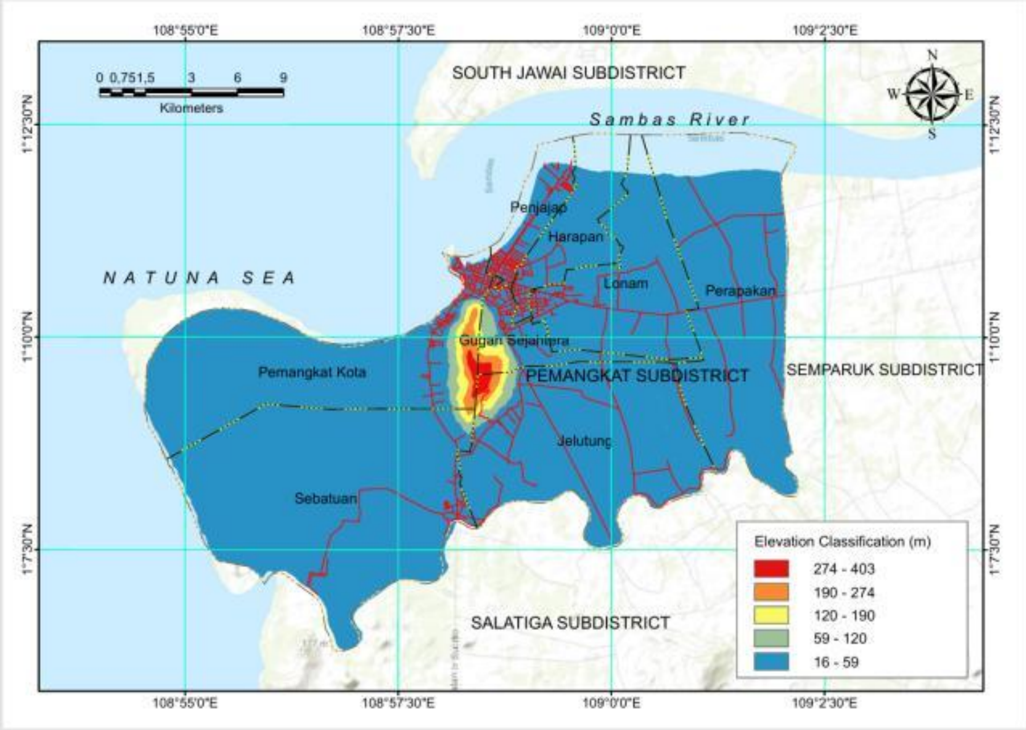

Figure 3. Elevation of Study Area

Source: DEM Sambas Regency

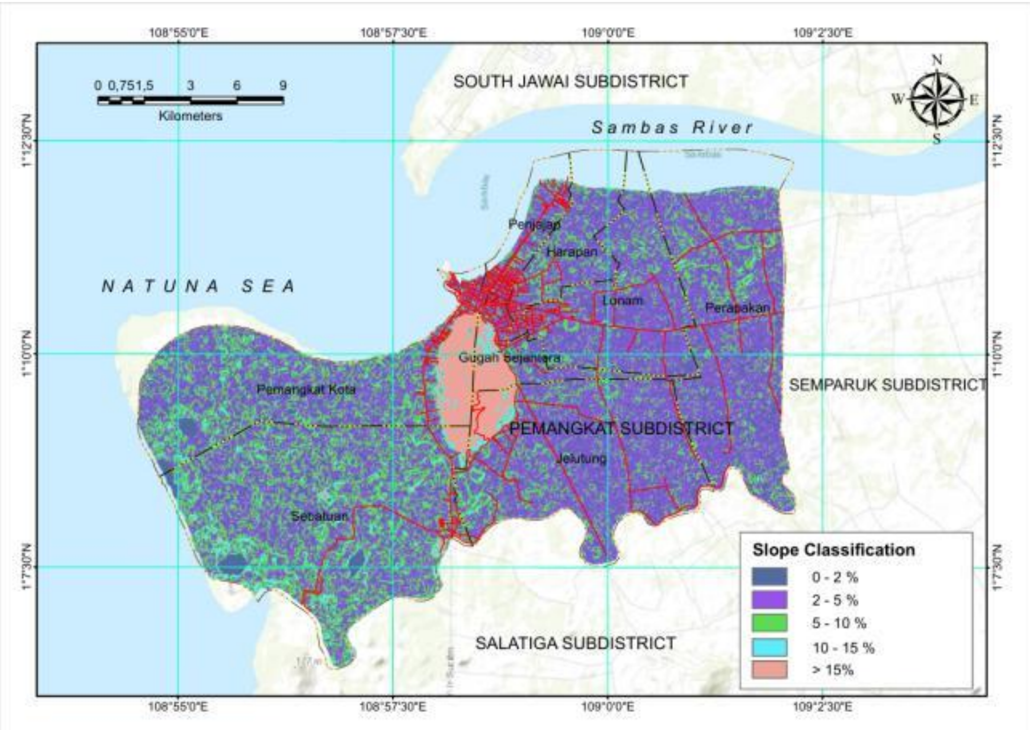

Figure 4. Slope Angel

Source: DEM Sambas Regency

2. Distance from Stream

Tidal flood events in the research area often occur in the coastal area. Streams contribute to increasing the supply of water flowing into the sea and can increase the height of tidal flood. Furthermore, the distance from the stream is created because the river flow will accommodate surface flow and carry some of the material on the surface of the water along the river route to the estuary (Mumbai, 2020). The distance from a river has a significant role in determining the distribution of floods in an area. Areas with low infiltration and percolation capabilities, sparse vegetation, and high slopes produce large amounts of runoff and cause flood disasters in downstream, and the coast. Distance from river research area can be seen in **Figure 5**.

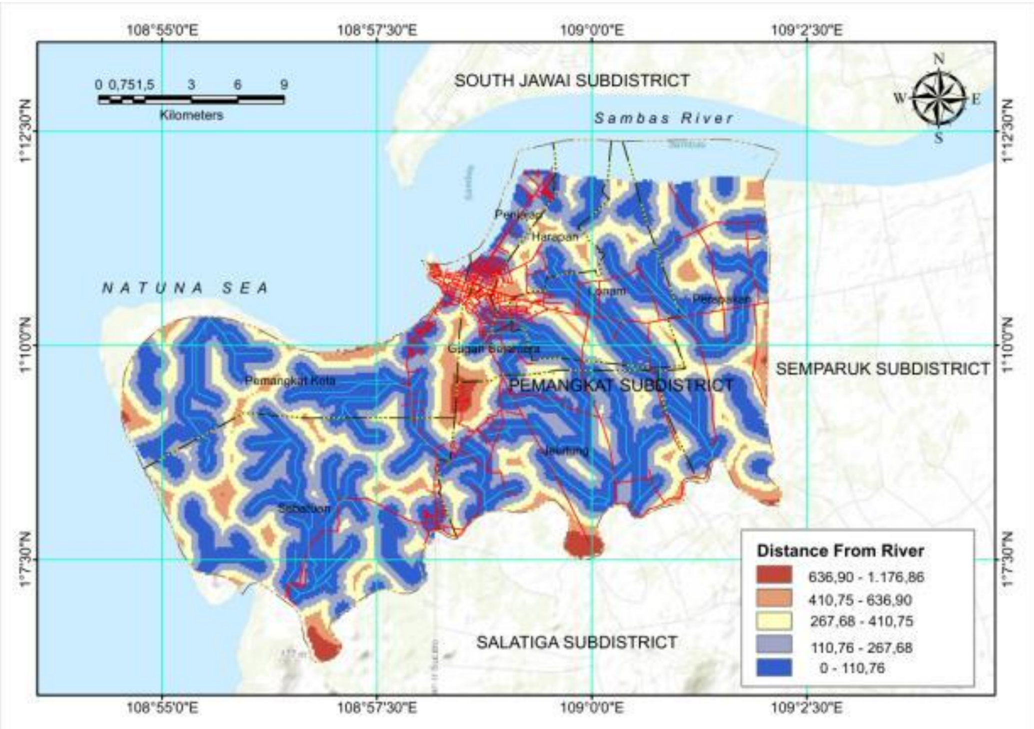

Figure 5. Distance from Stream
Source: DEM Sambas Regency

3. Precipitation

Precipitation data in the research area are used to produce annual precipitation maps. This precipitation map was created using the Inverse Distance Weighting (IDW) interpolation approach. precipitation in the research area varies. The precipitation classification used can be seen in **Figure 6**.

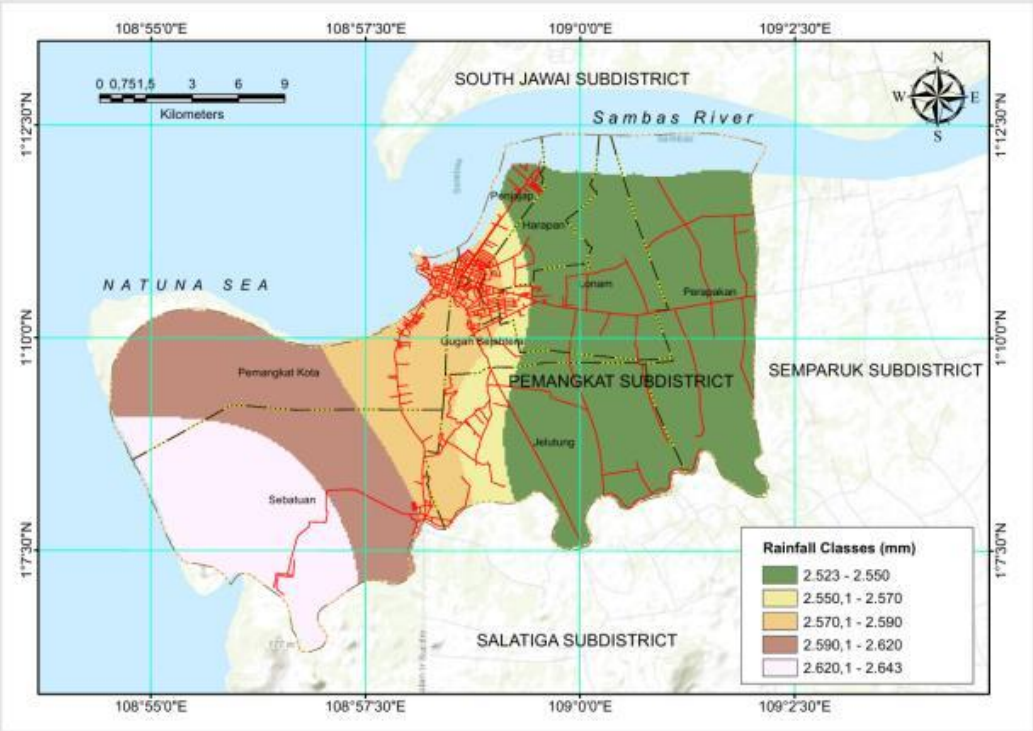

Figure 6. Precipitation

Source: CHIRPS 2025

4. Land Cover

Land cover influences changes in the flow system of the region (Mehr & Akdegirmen, 2021; Sugianto et al., 2022), as well as influencing infiltration capacity (Mehr & Akdegirmen, 2021). Low levels of vegetation cover will affect the infiltration rate, as well as change the acceleration of evapotranspiration (Nahib et al., 2021). This affects the balance of water evaporation (Sugianto et al., 2022) and water absorption as well as water distribution through rivers ((Nahib et al., 2021). Detailed studies of land cover are crucial for mitigating flood hazards. Land cover of the research area can be seen in **Figure 7**.

Pemangkat Subdistrict has a tidal flood classification, ranging from really low to high. Really high to high tidal flood disaster classes are scattered in Pemangkat and Sabatuan towns, while moderate to really low classes are in Jlutung village, Gugah Sejatera village, Penjajap village, Harapan village, Lonan village, and Parapakam village.

GeoEco, Vol. 12, No 2. July 2026 Page. 935 - 954
https://jurnal.uns.ac.id/GeoEco/article/view/115215

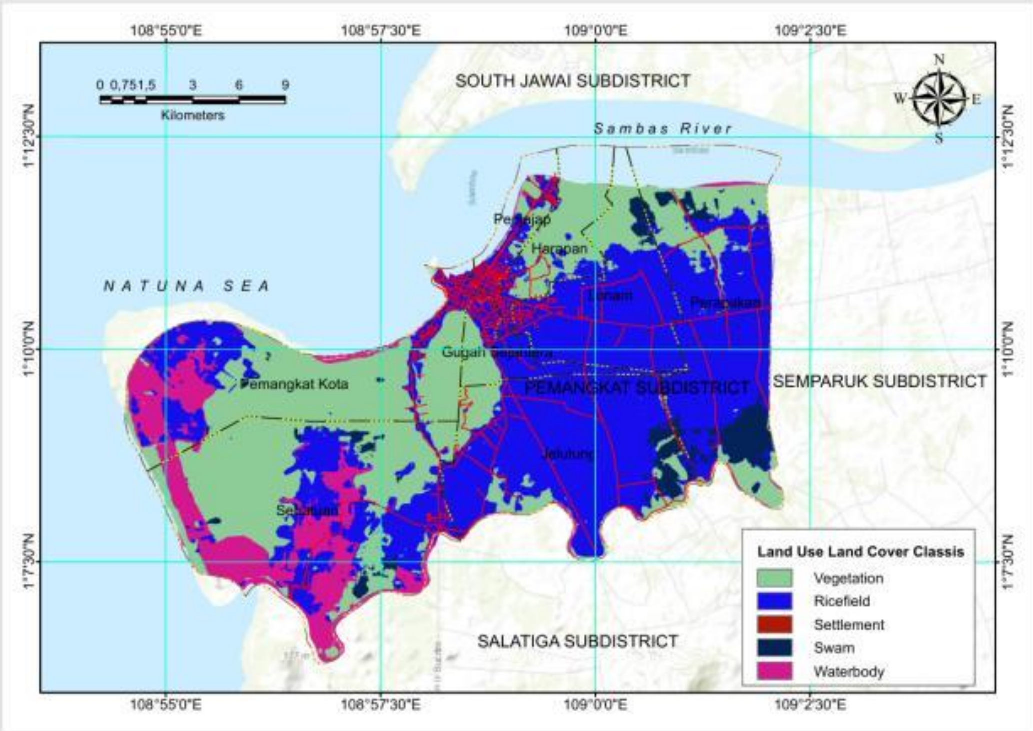

Figure 7. Land Cover

Source: Sentinel-2

Changes in precipitation naturally lead to changes in the hydrological systems. When people change the land by building things or cutting down trees, it can cause changes in water runoff. How changing the land we live on and the weather affects everything around us, in this case, precipitation leads to an increased risk of tidal flood and ecosystem changes. Increased population density in floodplains and increased development pressure in flood-prone areas lead to increased vulnerability of communities to flooding. The vulnerability to tidal flooding in the research area can be seen in **Figure 8**.

Mapping results show that tidal flood vulnerability in Pemangkat District is divided into five classes: very low, low, medium, high, and very high. The extent of tidal flood vulnerability can be seen in the **Table 3**.

Table 3. Level of Vulneraability Tidal Flooding

Tidal Flood Vulnerability Classes	Area (ha)	%
Very Low	8.17	8.16
Low	16.97	16.97
Moderat	28.17	28.16
High	32.28	32.28
Very High	14.41	14.39

Source: Secunder data analysis and Analytical Hierarchy Process (AHP)

https://doi.org/10.20961/ge.v12i2.115215
https://jurnal.uns.ac.id/GeoEco/article/view/115215

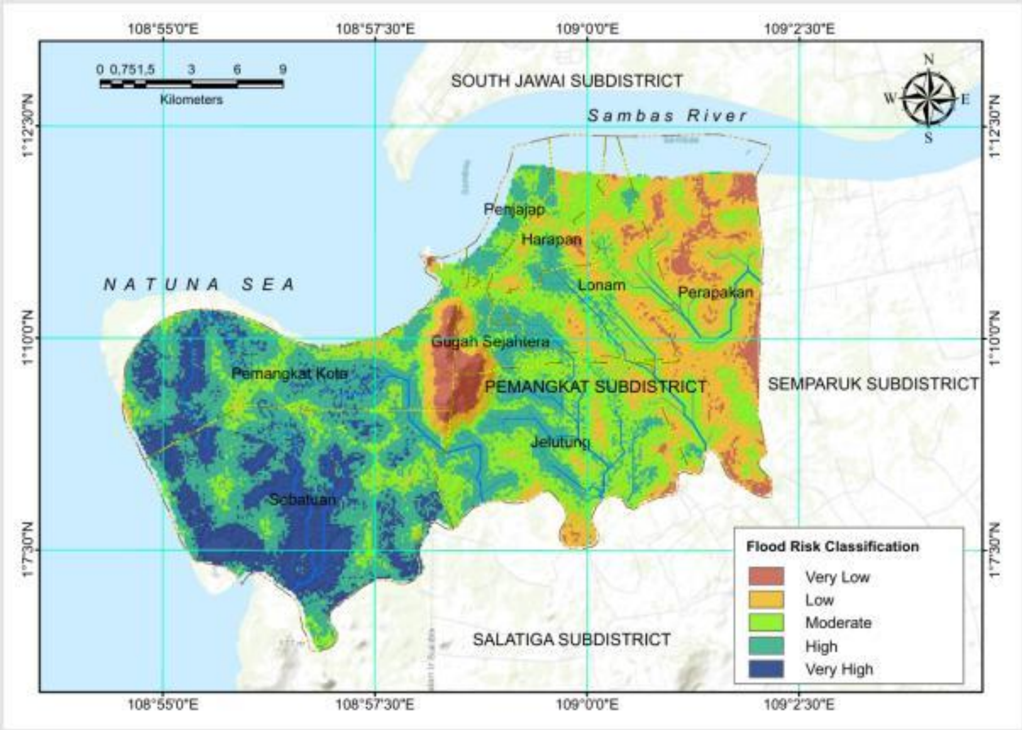

Figure 8. Tidal Flood Vulnerability Map

Source: Map Analysis and Field Survey

Spatially, areas with high to very high vulnerability levels are concentrated in Pemangkat Kota and Sebatuan, which are coastal areas located in lowlands adjacent to the coastline and tidal channels. The dominance of high and very high vulnerability levels, which reached 46.67% of the total area, indicates that nearly half of Pemangkat District has the potential for serious tidal flooding. This condition indicates the high influence of low elevation factors, proximity to tidal water bodies, and built-up land use, which reduce infiltration capacity. Conversely, areas with low to very low vulnerability levels are spread across the villages of Jelutung, Gugah Sejahtera, Penjajap, Harapan, Lonam, and Parapakan, with a total area of 25.14 ha (25.13%). These areas are generally located farther from the coast, have relatively higher elevations, or are still dominated by vegetation that can increase infiltration and reduce flooding.

The distribution pattern of vulnerability shows a clustered pattern in coastal areas and residential centers. The level of vulnerability increases toward coastal areas and river estuaries, then decreases inland. This pattern reflects the direct influence of tidal processes, which cause more frequent and extensive inundation in areas with low elevations and close to tidal channels. Furthermore, the moderate to high vulnerability class covers approximately 60.44% of the study area, indicating that most of Pemangkat District is vulnerable to tidal flooding. This distribution indicates that flood risk is not limited to the immediate coastal areas but also extends to transitional areas still affected by tidal dynamics.

The spatial pattern of tidal flood vulnerability in Pemangkat District shows a gradient of vulnerability from the coast to the interior, with the highest concentration of risk in the coastal areas of Pemangkat City and Sebatuan which require priority in tidal flood mitigation and adaptation planning. Adaptation can be achieved through the construction of permanent embankments, adaptive spatial planning that utilizes flood zones as fish ponds, relocating settlements to higher ground, and avoiding settlements in critical zones. Areas with moderate to very low tidal flooding are found in the villages of Jlutung, Gugah Sejatera, Penjajap, Harapan, Lonan, and Parapakam. Mitigation measures that can be implemented in these areas include building stilt houses, using water pumps at inundation points, constructing infiltration ponds, planting mangroves or sea pines, and improving drainage.

The results of this study show similarities with studies in Pekalongan and Semarang, namely high tidal flood vulnerability in coastal areas with low elevations, flat topography, and proximity to tidal bodies of water (Prabowo, 2021; Setyaningsih et al., 2024). However, unlike the North Coast of Java, which is strongly influenced by land subsidence and coastal urbanization (Ramadhani Maharlika et al., 2020), tidal flood vulnerability in Pemangkat District is more dominated by coastal geomorphology and tidal dynamics.

Validation of tidal flood vulnerability Tidal Flood Vulnerability in Pemangkat District can be seen **Table 4**.

Table 4. Validation of Tidal Flood Vulnerability in Pemangkat District

Risk Class	Number of tidal flood points	Occurred flooding	Flooding not occur
Very High	20	17	3
High	15	11	4
Moderate	15	8	7
Low	15	6	9
Very Low	10	2	8
Total	75	44	31

Source: Primary data analysis

Based on the table above, we can see:

- Overall Accuracy (OA) = 44 / 75 × 100% = 58%
- Producer Accuracy (incident points correctly predicted by the map) = 17 / 20 × 100% = 85%.
- User Accuracy (UA) (map predictions that accurately match the event) = 17 / (17 + 3) = 85%.
- Kappa Coefficient calculated to determine agreement above chance (≥ 0.6 = quite good).

The map shows quite good accuracy in the high and very high risk classes, proven to be in accordance with historical data (more than 80% accurate). Tidal flood events in Pemangkat District on January 25, 2023, March 2, 2023, June 2023, January 2025, and May 202 5 were associated with validation results with an overall accuracy of 58%, producer and user accuracy of 85% each, and a Kappa coefficient ≥ 0.6, providing a strong scientific basis for developing tidal flood adaptation and mitigation strategies in Pemangkat District. This validated model is able to map areas with high levels of vulnerability that spatially coincide with low-lying coastal areas, river estuaries, and densely populated residential areas that are frequently affected by tidal inundation. This information is crucial to support risk-based coastal mitigation and spatial planning, where areas with high levels of vulnerability can be prioritized in flood control programs, environmental rehabilitation, and drainage infrastructure improvements.

Areas with high validation, namely Pemangkat Kota and Sabatuan Villages, can immediately be prioritized for structural adaptation programs, such as embankment construction, road elevation, and stilt house construction. Areas with low accuracy require further research and policy development, taking into account socioeconomic factors, drainage, and extreme rainfall events. The validation results increase confidence in the model, allowing it to be used for spatial planning and tidal flood mitigation in Pemangkat.

The increasing frequency and intensity of tidal flood disasters due to climate change, sea level rise, and urbanization in coastal areas pose complex challenges for policymakers and city planners (Rodrigues et al., 2024; L. Xu et al., 2021). With the results of this study, adaptation and mitigation strategies in managing flood-impacted areas can be carried out effectively, using geospatial analysis as a decision-making tool

(Heinzlef et al., 2020; Rezvani et al., 2023; Torresan et al., 2016).

Adaptation and mitigation are like two sides of the same coin in climate resilience. In this study, adaptation has been shown to provide short-term relief in flood-prone areas by reducing exposure and increasing infrastructure resilience. For example, mitigation in areas vulnerable to flooding or overflowing water. Mitigation is less appropriate in protecting communities that already live with flooding every day. The conclusion is clear: adaptation is aimed locally and is temporary, while mitigation is globally oriented, but its impacts are delayed (Andrews et al., 2025; Díaz-Rodríguez et al., 2023; Sposato, 2016).

Geospatial data plays a critical role in mapping vulnerable zones at fine spatial resolution, modeling sea level rise and its impacts on specific urban areas, evaluating the effectiveness of flood defences, and tracking land use and emissions patterns for mitigation objectives. Integrating adaptation and mitigation alone is not enough to adequately manage tidal flood risk; an integrated strategy is needed. Geospatial data enables this integration by informing where adaptation is most needed, guiding mitigation through spatial analysis of emission hotspots and land cover change, and supporting scenario planning that combines short-term flood forecasts with long-term climate models (Doorga et al., 2025; Genc et al., 2025; Hawchar et al., 2020).

CONCLUSIONS

This study shows that Pemangkat District has varying levels of tidal flood vulnerability, ranging from very low to very high. Areas with high to very high vulnerability are concentrated in Pemangkat City and Sebatuan, which are characterized by lowlands and are close to coastal areas and tidal channels. Quantitatively, the high and very high vulnerability classes dominate at 46.67% of the total study area, thus indicating a high potential risk of tidal flooding in Pemangkat District. The model validation results show a good level of agreement with historical event data, indicated by Producer Accuracy and User Accuracy values of 85%.

These findings confirm that elevation, proximity to tidal water bodies, and land use are the main factors influencing tidal flood vulnerability. Therefore, the resulting vulnerability mapping can be the basis for mitigation and adaptation planning, such as embankment construction, coastal spatial management, drainage system improvement, and coastal ecosystem rehabilitation to reduce the risk of tidal flooding in Pemangkat District. A limitation of this study lies in the use of parameters that still focus on physical factors, without considering socio-economic aspects and sea-level rise scenarios.

REFERENCES

Ahmad, K. K., Putri, K. A., Wilujeung, A. D., Lestari, D. A., & Arifin, W. A. (2021). STATUS SEBARAN DAN KERAPATAN KANOPI MANGROVE DI PULAU TOBEA BESAR SULAWESI TENGGARA MENGGUNAKAN DATA SATELIT LANDSAT 8. *Pena Akuatika: Jurnal Ilmiah Perikanan Dan Kelautan*, *20*(2). https://doi.org/10.31941/penaakuatika.v20i2.1363

Ahmad, T. E., Rais, A., Azhari, D. R., Lestari, D. A., & Arifin, W. A. (2021). Penggunaan Iso Cluster Unsupervised Classification Dalam Mengenali Garis Pantai, Studi Kasus: Rarowatu Utara, Sulawesi Tenggara. *Seminar Nasional Ilmu Komputer (SNASIKOM)*, *1*(1), 53–69.

Andrews, T. M., Clark, R., & Perlman, R. (2025). *To Mitigate or Adapt? The Role of Climate Vulnerability on Policy Preferences*.

Almar, R., Ranasinghe, R., Bergsma, E. W. J., Diaz, H., Melet, A., Papa, F., Vousdoukas, M., Athanasiou, P., Dada, O., & Almeida, L. P. (2021). A global analysis of extreme coastal water levels with implications for potential coastal overtopping. *Nature Communications*, *12*(1), 3775. https://doi.org/10.1038/s41467-021-24008-9

Azhari, D. R., Lestari, D. A., & Arifin, W. A. (2022). Pemodelan Spasial Genangan Banjir Rob, Studi Kasus: Pesisir Utara Banten (Kecamatan Kasemen). *Jurnal Georafflesia: Artikel Ilmiah Pendidikan Geografi*, *7*(2), 173–181.

BPBD. (2025). *Laporan Banjir Rob Kabupaten Sambas*.

Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., & Mosavi, A. (2019). An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines. *Science of the Total Environment*, *651*, 2087–2096. https://doi.org/10.1016/j.scitotenv.2018.10.064

Díaz-Rodríguez, N., Del Ser, J., Coeckelbergh, M., de Prado, M. L., Herrera-Viedma, E., & Herrera, F. (2023). Connecting the dots in trustworthy Artificial Intelligence: From AI principles, ethics, and key requirements to responsible AI systems and regulation. *Information Fusion*, *99*, 101896. https://doi.org/10.1016/j.inffus.2023.101896

Doorga, J. R. S., Pasnin, O., & Dindoyal, Y. (2025). From risk to resilience: geospatial decision support tool and adaptation strategies for coastal flooding in Rodrigues Island. *Climatic Change*, *178*(5), 1–23. https://doi.org/10.1007/s10584-025-03930-7

Genc, N., Colak, H. E., & Baser, V. (2025). Towards Sustainable Futures: An Interdisciplinary Bridge—A Bibliometric Review on Climate Change, Agriculture, Land Management, and GIS. *Sustainable Development*. https://doi.org/10.1002/sd.3439

Hamuna, B., Sari, A. N., & Alianto, A. (2018). Kajian kerentanan wilayah pesisir ditinjau dari geomorfologi dan elevasi pesisir Kota dan Kabupaten Jayapura, Provinsi Papua. *Jurnal Wilayah Dan Lingkungan*, *6*(1), 1–14. https://doi.org/10.14710/jwl.6.1.1-14

Hawchar, L., Naughton, O., Nolan, P., Stewart, M. G., & Ryan, P. C. (2020). A GIS-based framework for high-level climate change risk assessment of critical infrastructure. *Climate Risk Management*, *29*, 100235. https://doi.org/10.1016/j.crm.2020.100235

Heinzlef, C., Becue, V., & Serre, D. (2020). A spatial decision support system for enhancing resilience to floods: Bridging resilience modelling and geovisualization techniques. *Natural Hazards and Earth System Sciences*, *20*(4), 1049–1068. https://doi.org/10.5194/nhess-20-1049-2020

Iskandar, S. A., Helmi, M., Muslim, M., Widada, S., & Rochaddi, B. (2020). Analisis Geospasial Area Genangan Banjir Rob dan Dampaknya pada Penggunaan Lahan Tahun 2020-2025 di Kota Pekalongan Provinsi Jawa Tengah. *Indonesian Journal of Oceanography*, *2*(3), 271–282. https://doi.org/10.14710/ijoce.v2i3.8668

Lestari, D. A., Fitriasari, N. S., Ahmad, T. E., Rais, A., & Azhari, D. R. (2021). Spatial Analysis on Tsunami Predictions in Pandeglang Regency. *Forum Geografi*, *35*(1), 103–115. https://doi.org/10.23917/forgeo.v35i1.12367

Li, Z., Mount, J., & Demir, I. (2020a). *Evaluation of model parameters of HAND model for real-time flood inundation mapping: iowa case study*. eartharxiv.org. https://eartharxiv.org/repository/object/127/download/262/.

Li, Z., Mount, J., & Demir, I. (2020b). *Model Parameter Evaluation and Improvement for Real-Time Flood Inundation Mapping Using HAND Model: Iowa Case Study*. eartharxiv.org. https://eartharxiv.org/hqpzg/https://doi.org/10.31223/OSF.IO/HQPZG

Mehr, A. D., & Akdegirmen, O. (2021). Estimation of urban imperviousness and its impacts on flashfloods in Gazipaşa, Turkey. *Knowledge-Based Engineering and Sciences*, *2*(1), 9–17. https://doi.org/10.51526/kbes.2021.2.1.9-17

Mumbai, G. (2020). frequency ratio and fuzzy gamma operator models in GIS : a case study of Urban flood susceptibility zonation mapping using evidential belief function , frequency ratio and fuzzy gamma operator models in GIS : a case study of Greater Mumbai , Maharashtra ,. *Geocarto International*, *0*(0), 1–26. https://doi.org/10.1080/10106049.2020.1730448. https://doi.org/10.1080/10106049.2020.1730448

Nahib, I., Ambarwulan, W., Rahadiati, A., Munajati, S. L., & Prihanto, Y. (2021). *Assessment of the Impacts of Climate and LULC Changes on the Water Yield in the Citarum River Basin , West Java Province , Indonesia*. https://doi.org/10.3390/su13073919

Pontianak Post. (2023). *Banjir Rob di Pemangkat Rendam Ratusan Rumah Warga*.

Pourali, S. H., Arrowsmith, C., Chrisman, N., Matkan, A. A., & Mitchell, D. (2018). Topography wetness index application in flood-risk-based land use planning. *Applied Spatial Analysis and Policy*, *9*, 39–54. https://doi.org/10.1007/s12061-014-9130-2

Prabowo, A. (2021). Pemanfaatan Citra Landsat 8 Dan Data Dem Untuk Mengetahui Tingkat Kerentanan Dan Mitigasi Banjir Rob Di Daerah Pekalongan, Jawa Tengah. *ReTII*, 408–416.

Purwanto, A., & Paiman, P. (2023). Flood Risk Spatial Modeling Based on Geographical Information Systems and Remote Sensing in the Pemangkat Regensi. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9554–9563. https://doi.org/10.29303/jppipa.v9i11.5264

Putiamini, S., Patria, M. P., Soesilo, T. E. B., & Karsidi, A. (2023). Coastal vulnerability assessment to tidal (rob) flooding in Indramayu Coast, West Java, Indonesia. *Indonesian Journal of Geography*, *55*(3), 517–526. https://doi.org/10.22146/ijg.65549

Ramadhani Maharlika, A., Prawata Hadi, S., Kismartini, & Lenty Hoya, A. (2020). Tidal flooding and coastal adaptation responses in Pekalongan City. *E3S Web of Conferences*, *202*, 6027. https://doi.org/10.1051/e3sconf/202020206027

Ramesh, V., & Iqbal, S. S. (2022). Urban flood susceptibility zonation mapping using evidential belief function, frequency ratio and fuzzy gamma operator models in GIS: a case study of Greater Mumbai, Maharashtra, India. *Geocarto International*, *37*(2), 581–606. https://doi.org/10.1080/10106049.2020.1730448

Rezvani, S. M. H. S., Falcão, M. J., Komljenovic, D., & de Almeida, N. M. (2023). A systematic literature review on urban resilience enabled with asset and disaster risk management approaches and GIS-based decision support tools. *Applied Sciences*, *13*(4), 2223. https://doi.org/10.3390/app13042223

Riadi, B. (2018). *Model Spasial Banjir Untuk Mendukung Ketersediaan Pangan di Kabupaten Karawang.*

Rodrigues, E. A., Carvalho, A. R. de, Ferreira, M. L., Victor, R. A. B. M., Luca, E. F. de, Rocha, G. C. da, Carvalho, B. R. de, Bustillos, J. O. W. V., Sodré, M. G., & Oliveira, M. C. (2024). Beyond the

Rising Tide: Towards Effective Climate Policy in Coastal Urban Centers. *Land*, *13*(12), 2071. https://doi.org/10.3390/land13122071

Rosser, J. F., Leibovici, D. G., & Jackson, M. J. (2017). Rapid flood inundation mapping using social media, remote sensing and topographic data. In *Natural Hazards*. Springer. https://doi.org/10.1007/s11069-017-2755-0. https://doi.org/10.1007/s11069-017-2755-0

Sayama, T., Tatebe, Y., Iwami, Y., & Tanaka, S. (2015). Hydrologic sensitivity of flood runoff and inundation: 2011 Thailand floods in the Chao Phraya River basin. *Natural Hazards and Earth System Sciences*, *15*(7), 1617–1630. https://doi.org/10.5194/nhess-15-1617-2015

Sermet, Y., Villanueva, P., Sit, M. A., & Demir, I. (2020). Crowdsourced approaches for stage measurements at ungauged locations using smartphones. *Hydrological Sciences Journal*, *65*(5), 813–822. https://doi.org/10.1080/02626667.2019.1659508

Setyaningsih, W., Saputro, P. A., Indrayati, A., Kurniawan, E., Syifauddin, M., Wijaya, V., & Mahat, H. (2024). Spatial-Temporal Distribution and Vulnerability Level of Tidal Flooding in the Coastal City of Semarang. *International Journal of Safety & Security Engineering*, *14*(5). https://doi.org/10.18280/ijsse.140527

Singh, Y. K., Dutta, U., Prabhu, T. S. M., Prabu, I., Mhatre, J., Khare, M., Srivastava, S., & Dutta, S. (2017). Flood response system—A case study. *Hydrology*, *4*(2), 30. https://doi.org/10.3390/hydrology4020030

Sposato, R. G. (2016). *Public engagement with climate change in light of a more balanced policy focus on adaptation and mitigation*. Cardiff University.

Sugianto, S., Deli, A., Miswar, E., Rusdi, M., & Irham, M. (2022). The Effect of Land Use and Land Cover Changes on Flood Occurrence in Teunom Watershed, Aceh Jaya. *Land*, *11*(8). https://doi.org/10.3390/land11081271.

Teng, J., Jakeman, A. J., Vaze, J., Croke, B. F. W., Dutta, D., & Kim, S. (2017). Flood inundation modelling: A review of methods, recent advances and uncertainty analysis. *Environmental Modelling & Software*, *90*, 201–216. https://doi.org/10.1016/j.envsoft.2017.01.006

Torresan, S., Critto, A., Rizzi, J., Zabeo, A., Furlan, E., & Marcomini, A. (2016). DESYCO: A decision support system for the regional risk assessment of climate change impacts in coastal zones. *Ocean & Coastal Management*, *120*, 49–63. https://doi.org/10.1016/j.ocecoaman.2015.11.003

Vitousek, S., Barnard, P. L., Fletcher, C. H., Frazer, N., Erikson, L., & Storlazzi, C. D. (2017). Doubling of coastal flooding frequency within decades due to sea-level rise. *Scientific Reports*, *7*(1), 1399.

Xiang, Z., & Demir, I. (2020).

Distributed long-term hourly streamflow predictions using deep learning–A case study for State of Iowa. *Environmental Modelling & Software*, *131*, 104761. https://doi.org/10.1016/j.envsoft.2020.104761

Xu, H., Windsor, M., Muste, M., & Demir, I. (2020). A web-based decision support system for collaborative mitigation of multiple water-related hazards using serious gaming. *Journal of Environmental Management*, *255*, 109887. https://doi.org/10.1016/j.jenvman.2019.109887

Xu, L., Cui, S., Wang, X., Tang, J., Nitivattananon, V., Ding, S., & Nguyen, M. N. (2021). Dynamic risk of coastal flood and driving factors: Integrating local sea level rise and spatially explicit urban growth. *Journal of Cleaner Production*, *321*, 129039. https://doi.org/10.1016/j.jclepro.2021.129039

Yildirim, E., & Demir, I. (2021). An integrated flood risk assessment and mitigation framework: A case study for middle Cedar River Basin, Iowa, US. *International Journal of Disaster Risk Reduction*, *56*, 102113. https://doi.org/10.1016/j.ijdrr.2021.102113