

SPATIAL ANALYSIS OF FLOOD SUSCEPTIBILITY AND ITS IMPACT ON EDUCATIONAL FACILITIES IN TANGERANG CITY

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ABSTRAK

Abstrak: Banjir merupakan bencana hidrometeorologi yang menyebabkan kerusakan luas serta menimbulkan kerugian di bidang ekonomi, kesehatan, dan pendidikan. Penelitian ini menganalisis distribusi spasial kerawanan banjir dan kaitannya dengan lokasi fasilitas pendidikan di Kota Tangerang. Pendekatan kuantitatif diterapkan dengan menggunakan metode *Weighted Sum* yang terintegrasi dalam Sistem Informasi Geografis (SIG) serta melibatkan berbagai parameter fisik dan antropogenik. Hasil analisis menunjukkan bahwa kelas kerawanan sedang dan tinggi mendominasi, masing-masing mencakup sekitar 6.300 ha dan 6.574 ha, sedangkan kelas sangat tinggi mencapai 2.022 ha. Sekitar 78,6% fasilitas pendidikan berada pada wilayah dengan tingkat risiko banjir sedang hingga sangat tinggi. Kecamatan dengan tingkat kerawanan tertinggi meliputi Tangerang, Ciledug, dan Pinang, sedangkan Batuceper, Neglasari, dan Benda tergolong rendah hingga sangat rendah. Temuan ini menegaskan bahwa curah hujan, topografi, jenis tanah, dan lahan terbangun berperan penting dalam menentukan kerawanan banjir, serta menjadi dasar mitigasi risiko fasilitas pendidikan dan kebijakan tata ruang wilayah.

Kata Kunci: *Banjir, Sistem Informasi Geografi, Weight Sum, Fasilitas Pendidikan, Mitigasi*

Abstract: *Floods are hydrometeorological disasters that cause extensive damage and lead to economic, health, and educational losses. This study analyzes the spatial distribution of flood susceptibility and its relationship with educational facilities in Tangerang City. A quantitative approach was applied using the Weighted Sum method integrated with Geographic Information Systems (GIS) and multiple physical and anthropogenic parameters. The results show that moderate and high susceptibility classes dominate, covering approximately 6,300 ha and 6,574 ha, while the very high class reaches 2,022 ha. About 78.6% of educational facilities are located in areas with moderate to very high flood risk. Districts with the highest susceptibility include Tangerang, Ciledug, and Pinang, whereas Batuceper, Neglasari, and Benda show low to very low risk. These findings highlight the interaction of rainfall, topography, soil type, and built-up land in shaping flood Susceptibility and provide a basis for educational facility risk mitigation and spatial planning policies.*

Keywords: *Flood, Geographic Information System, Weighted Sum, Educational Facilities, Mitigation*

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A. BACKGROUND

Floods are among the most destructive hydrometeorological disasters in the world (Lancet Countdown, 2022), causing economic losses and significant impacts on health and infrastructure (Kenyi, 2020). The trend and frequency of floods are increasing due to climate change and uncontrolled urbanization in developing countries (Dossa et al., 2025). In Indonesia, floods cause losses of trillions of rupiahs annually and have significant impacts (BNPB, 2025) such as worsening economic and public health conditions and reducing the quality of education (Haque et al., 2023). Jabodetabek serves as the educational center and has a high level of flood risk (Rustiadi et al., 2015), Tangerang City, as part of Jabodetabek, has a high population density and relatively complete educational facilities (Pribadi et al., 2022). This condition indicates the urgency of developing a Susceptibility map as a mitigation step in the future.

Flooding is the overflow of water that covers land areas caused by rainfall, river overflow, or sea-level rise (WMO, 2021). According to (UNISDR, 2020), floods are the interaction between hydrometeorological hazards and Susceptibility levels, influenced by land-use patterns, climate change, and socio-economic dynamics. Causes of flooding include high rainfall intensity, reduced drainage capacity, land-use changes, and decreased infiltration areas due to urbanization (Adelekan et al., 2022). Land conversion from green areas to densely populated settlements in Tangerang City, especially along the Cisadane River, increases the potential for flooding (Rahman et al., 2024). Moreover, poor drainage systems and low-lying topography exacerbate flooding (Susanti & Nugroho, 2023).

Flood Susceptibility is the probability level of an area experiencing flooding (Kwak et al., 2023), which, in this context, relates to the location of educational facilities. Numerous studies on flood Susceptibility have been conducted, but few have linked it to educational facility locations, even though these facilities represent vital and vulnerable social infrastructure (Abebe et al., 2021). To address this research gap, this study applies a spatial analysis approach with key parameters including distance from rivers, land use/land cover, distance from roads, rainfall, soil type, elevation, and slope (Hosseini et al., 2022). The distance from rivers determines direct runoff potential, land use reflects land absorption capacity, distance from roads illustrates artificial drainage patterns, rainfall determines hazard intensity, soil type influences infiltration, while elevation and slope control surface water flow (Abidin et al., 2024; Islam et al., 2023; Pham et al., 2021).

Spatial approaches to assessing flood susceptibility can employ quantitative methods such as the Analytic Hierarchy Process (AHP), Frequency Ratio (FR), Logistic Regression (LR), and Machine Learning (ML) models like Random Forest (RF), as well as index-based approaches such as Weighted Overlay (Khosravi et al., 2021). Statistical methods such as FR and LR excel in identifying quantitative relationships between environmental parameters and flood events, while machine learning approaches capture nonlinear patterns with high accuracy but require complete and reliable historical data (Pham et al., 2023). In this study, the Weighted Sum method was selected because it integrates various parameters with importance weights determined through empirical studies and literature (Sahana & Sajjad, 2022). The strength of this method lies in its simplicity, interpretability, and high compatibility, while its weakness is the subjectivity in weight

determination, which can affect final outcomes (Shafizadeh-Moghadam et al., 2023). Given the limited historical flood data and parameter availability, this method is relevant for Tangerang City (Utami et al., 2024).

This study has two purposes: it aims to analyse the spatial distribution of flood susceptibility in Tangerang city, and to analyze its relationship with the location of educational facilities in Tangerang City. The analysis is expected to produce spatial mapping that can be used for decision-making in spatial planning and disaster risk mitigation (Rahman et al., 2024). Theoretically, the study presents an integrative model combining biophysical parameters and social infrastructure (Adelekan et al., 2022). Practically, it serves as a foundation for local governments to develop mitigation strategies for educational facilities and helps educational institutions understand the Susceptibility levels within their environment (Haque et al., 2023; Marfai et al., 2021).

B. METHOD

1. Study Area

Tangerang City is geographically located between $6^{\circ}05' - 6^{\circ}15'$ S and $106^{\circ}33' - 106^{\circ}44'$ E. The city has 13 sub-districts and experienced rapid population growth, reaching more than 1.8 million people over the past decade (BPS, 2024), which has increased the demand for educational facilities. Based on Figure 1, this study used 98 educational facility locations. Climatologically, the city has a tropical monsoon climate with a relatively high annual rainfall intensity, ranging from 2.000–2500 mm per year, peaking during December–February (Badan Meteorologi Klimatologi dan Geofisika, 2022). The city lies in lowland areas with an elevation of 0–18 meters above sea level (BPS, 2024). In addition, land-use changes, particularly the conversion of green and infiltration zones into built-up areas, have increased the potential for flooding (Pribadi et al., 2022). Besides that, Tangerang is one of the city that focus on the improvement of quality education (BPS, 2024).

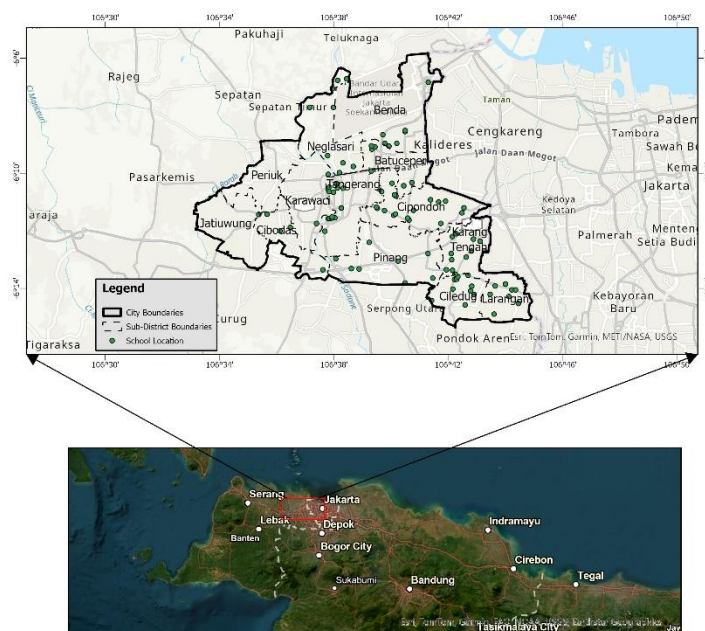


Figure 1. Location Study of Tangerang City

2. Data Collection

This study used various spatial datasets to analyze flood susceptibility in relation to school locations in Tangerang City. Land-use data were derived from Sentinel-1

imagery to classify land cover types. The distance from rivers and school locations was obtained from the *Rupa Bumi Indonesia* (RBI) maps of the Geospatial Information Agency (BIG). Rainfall data were sourced from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS), which provided good spatial resolution and extensive temporal coverage. Slope and elevation data were extracted from the Digital Elevation Model Nasional (DEMNAS) developed by BIG. All datasets were used to generate explanatory variables for flood susceptibility and to identify schools located in risk-prone areas (Asfaw et al., 2023; Guzha et al., 2022).

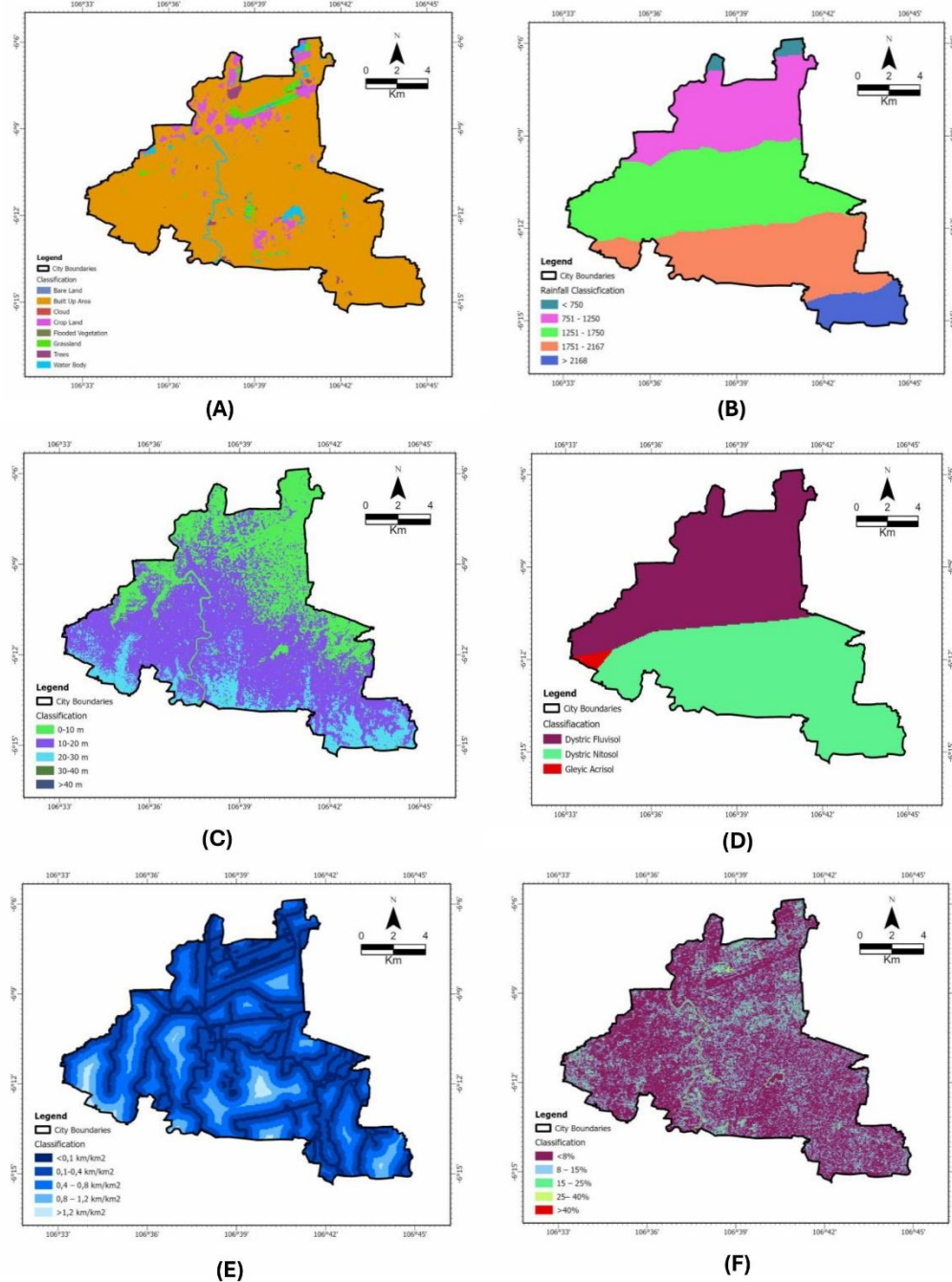


Figure 2. Parameter Data (A) Land Use Land Change, (B) Rainfall, (C) Elevation, (D) Soil Types, (E) Distance to River, (F) Slope

3. Data Analysis

The Weighted Sum method (also referred to as Weighted Linear Combination or Simple Additive Weighting) is a criterion aggregation method in multi-criteria analysis that produces scores and weights for each parameter by summing the product of the criterion score and its corresponding weight (Malczewski, 1999). This method is part of the Spatial Multi-Criteria Analysis (SMCA) framework. Within the geographic information system environment, the Weighted Sum approach requires that each criterion map be normalized to a comparable scale before weights are applied so that the aggregated results are spatially meaningful (Eastman, 2012). In this study, scoring was performed on a scale of 1 to 5. Each parameter was assigned a weight based on previous literature which can be seen in Table 1. Parameters of this study are literature that consists of soil types, rainfall, distance to river, land use land cover (LULC), slope, and elevation.

The formula for the Weighted Sum method is as follows:

$$S_i = \sum (W_j \times X_{ij}) \dots\dots\dots (1)$$

where S_i represents the aggregate score for the i -th spatial location, W_j denotes the relative weight of the j -th criterion, and X_{ij} is the normalized value of the j -th criterion at the i -th location (Malczewski, 1999).

The main advantage of the Weighted Sum method lies in its simplicity of computation and interpretability (Eastman, 2012). It can integrate multiple types of raster data (Malczewski, 1999). However, this method assumes linear and additive contributions of each criterion, disregarding potential interactions among parameters (Malczewski, 2006). Another limitation is subjectivity in weight assignment, which can influence final results (Sahana & Sajjad, 2022). To mitigate this limitation, weights were determined through an extensive literature review (Malczewski, 2006; Shafizadeh-Moghadam et al., 2023).

Table 1. Scoring and Weighting each Parameter

Parameter	Classification	Weight (%)	Scoring	Reference
Land Use Land Cover (LULC)	Built Up Area, Flood Vegetation, Water Body	20	5	(Fauzi & Handayani, 2024)
	Bare Land		4	
	Crop Land		3	
	Grassland		2	
	Trees		1	
Elevation	0-10 m	15	5	(D. W. Putra et al., 2023)
	10-20 m		4	
	20-30 m		3	
	30-40 m		2	
	>40 m		1	
Slope	<8%	15	5	(Prasetyo & Wulandari, 2023)
	8-15%		4	
	15-25%		3	
	25-40%		2	
	>40%		1	
Rainfall	>2168	20	5	(Wibowo et al., 2022)
	1751 - 2167		4	
	1251 - 1750		3	
	751 - 1250		2	
	<750		1	

Soil Types	Gleyic Acrisol	15	5	(Dewi & Nurlela, 2023)
	Dystric Fluvisol		3	
	Dystric Nitosol		1	
Distance to River	<0,1 km/km ²	15	5	(Setiawan et al., 2023)
	0,1 - 0,4 km/km ²		4	
	0,4 - 0,8 km/km ²		3	
	0,8 - ,2 km/km ²		2	
	>1,2 km/km ²		1	

C. RESULT AND DISCUSSION

1. Spatial Distribution of Flood Susceptibility

The spatial distribution map based on Figure 3 that Tangerang City exhibits varying levels of flood Susceptibility. High and very high susceptibility areas are predominantly located in the central and northern parts, including the districts of Karawaci, Tangerang, Batuceper, Cipondoh, and parts of Neglasari and Benda. In contrast, areas classified as low to very low susceptibility are found mainly in the southern region, such as Pinang, Ciledug, Larangan, and parts of Jatiuwung. This spatial pattern indicates that areas with intense urbanization and high building density tend to have higher flood susceptibility levels.

Figure 4 shows that the moderate and high susceptibility classes dominate the land area of Tangerang City, covering approximately 6.300 hectares and 6.574 hectares, respectively. These two classes suggest that most of the city is at moderate to high risk of flooding, closely related to hydrological factors, land-use changes, and an increasing proportion of built-up areas. Meanwhile, the very high susceptibility class occupies 2.022 hectares, indicating critical flood-prone zones requiring special attention and intervention.

Conversely, areas with low and very low susceptibility cover 2.723 hectares and 114 hectares, respectively. This data reflects that Tangerang City has some areas with relatively good capacity to withstand flooding. Overall, the city faces significant challenges in flood mitigation, particularly in densely built-up regions. These findings form the basis for identifying causal factors and formulating effective mitigation strategies (Ikhvan & Mera, 2021).

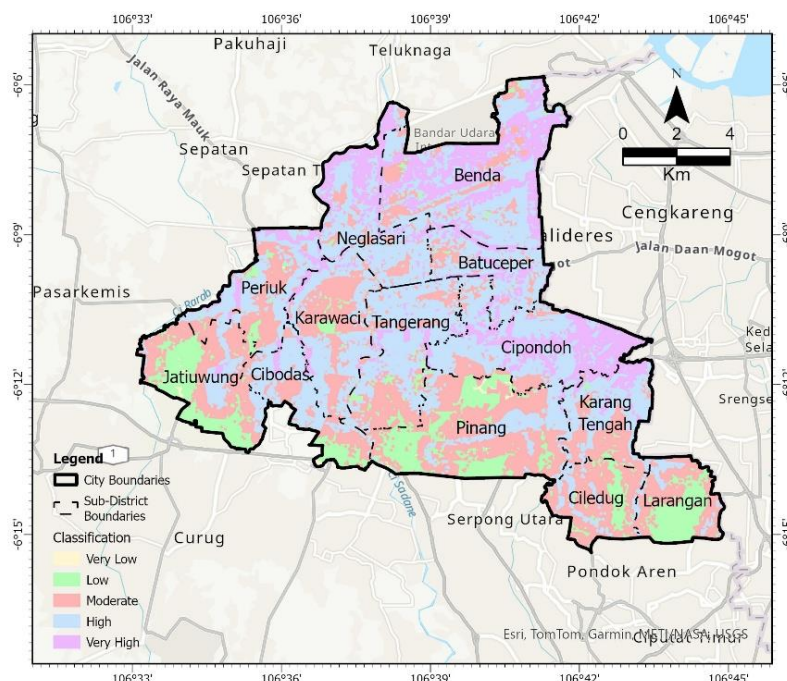


Figure 3. Spatial Distribution of Flood Susceptibility

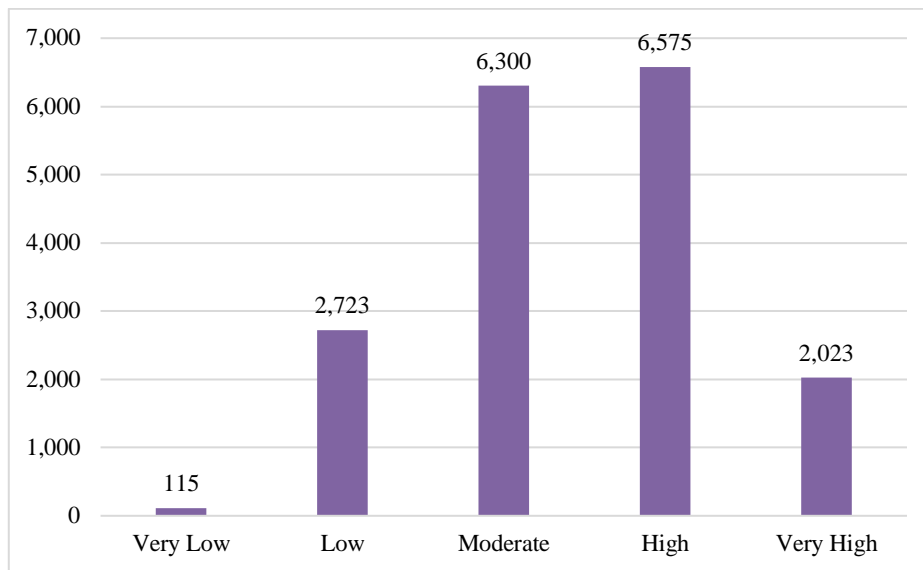


Figure 4. Wide Distribution of Susceptibility Level

2. Distribution of Educational Facilities and Flood Susceptibility

The analysis describes that educational facilities within the study area are significantly affected by flood susceptibility based on Figure 5. Approximately 78.6% of the total 98 educational facilities are located in areas of moderate to very high flood risk — with 38 schools in the moderate category, 39 in high, and 7 in very high risk zones.

Additionally, Figure 6 shows that three areas exhibit the highest susceptibility to flooding: Tangerang (11 schools), Ciledug (9 schools), and Pinang (9 schools). Each of these sub-districts falls within high and very high flood zones. Meanwhile, sub-districts with the lowest flood risk include Batuaceper, Neglasari, and Benda, each having fewer than three schools.

The high susceptibility observed in Tangerang, Ciledug, and Pinang is influenced by the interaction of physical parameters—particularly elevation and slope. These districts are mostly located in low-lying areas (0–10 m elevation) with gentle slopes (<8%) and are classified as alluvial plains or basins. Such geomorphological conditions slow down surface runoff and increase water accumulation potential (Prasetyo & Wulandari, 2023; R. Putra & Prasetyo, 2021).

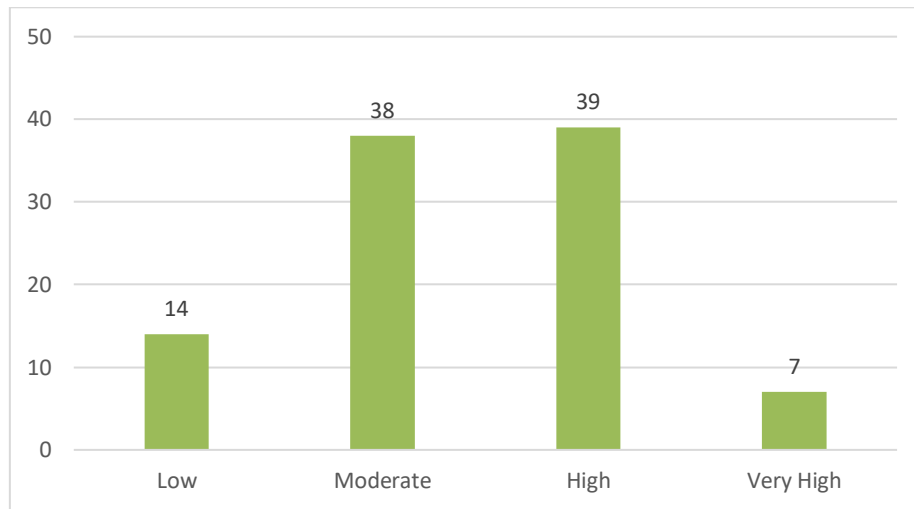


Figure 5. Total Education Facility to Each Level Susceptibility

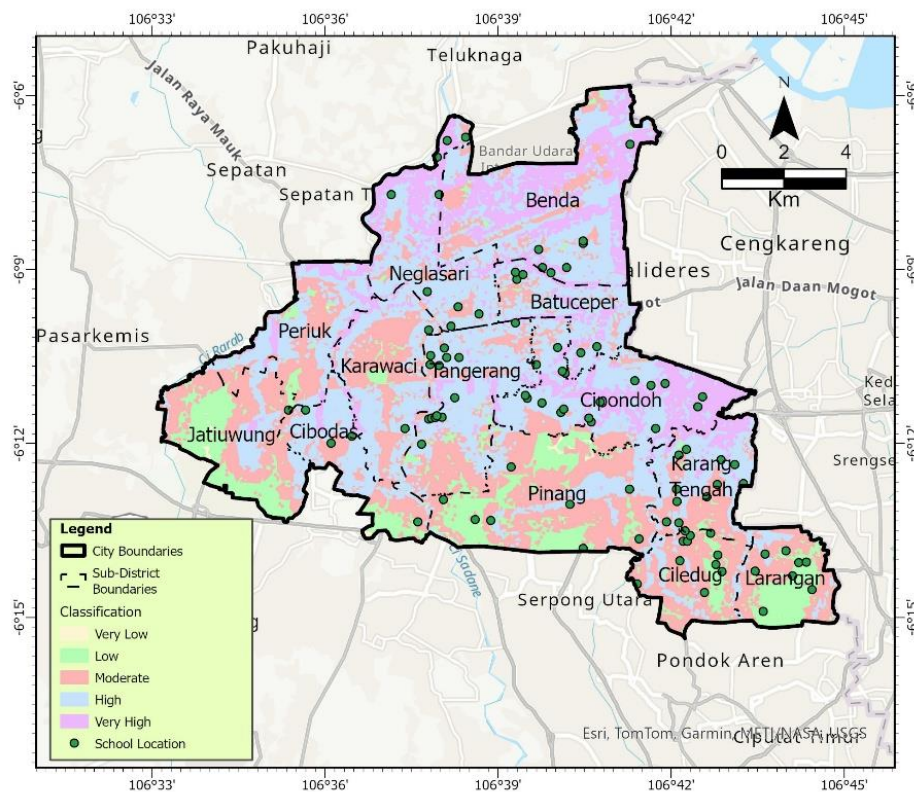


Figure 6. Spatial Distribution of Education Facilities Correlated with Susceptibility Level.

3. Discussion

Tangerang City exhibits significant flood susceptibility, with most of its area classified the moderate and high susceptibility covering approximately 6.300 hectares and 6.574 hectares, respectively. Additionally, 78.6% of educational facilities are located in areas of moderate to very high flood risk. The spatial concentration of susceptibility in the central and eastern regions—particularly in Tangerang, Pinang, and Ciledug Districts—demonstrates a strong correlation between flood risk levels and dominant physical parameters.

The city's high susceptibility is intrinsically related to low topographic conditions that impede surface runoff (R. Putra & Prasetyo, 2021). This is further exacerbated by anthropogenic factors such as extensive built-up areas that reduce infiltration capacity and accelerate surface runoff (Fauzi & Handayani, 2024). Furthermore, the dominance of Gleyic Acrisol soils, characterized by low permeability, contributes to persistent surface water accumulation (Dewi & Nurlela, 2023). Thus, the city's high flood susceptibility results from the complex interaction of physical factors—such as elevation, slope, and soil types—and anthropogenic factors, particularly land use land change.

Drawing from other studies on flood vulnerability in urban areas, Gupta & Dixit (2023) notes that dense urbanization and the loss of green spaces heighten flood occurrences in Kampur, India. High rainfall levels, especially on monsoon season, further exacerbate flooding in Mumbai (Manna et al., 2025). In Malaysia, specifically Taman Sri Muda in Selangor, elevation and slope gradient emerge as key influencing factors (Sukri et al., 2025). Thus, each city exhibits unique characteristics in its driving factors, shaped by local geography and mitigation policies.

On the other hand, this study provides substantive benefits for decision-making and urban spatial policy formulation. The flood susceptibility map, when overlaid with educational facility locations, offers specific and actionable information for disaster mitigation planning. The primary policy implication is the need to reinforce educational infrastructure and consider relocating schools situated in high and very high-risk zones, particularly in Tangerang, Ciledug, and Pinang Districts. Practically, these findings can be integrated into the Regional Spatial Plan (RTRW) and Detailed Spatial Plan (RDTR), accompanied by regulations limiting new public infrastructure development in moderate-risk zones. Furthermore, the study provides a foundation for disaster education programs tailored to the risk levels of individual schools (Wibowo et al., 2022).

Although this study successfully mapped flood susceptibility with high spatial resolution (approximately 30 meters), several limitations must be acknowledged. First, the model is static (multi-criteria overlay) and does not account for temporal and hydrodynamic variations in flood events, such as depth and duration of inundation measured using 2D hydraulic modeling (Zheng et al., 2020). Second, the parameter weights were determined based on a literature review and expert judgment, which could be improved using more objective methods such as the Analytic Hierarchy Process (AHP) involving expert participation. Future studies should integrate variables such as micro-drainage infrastructure capacity and historical loss data to improve the accuracy of Susceptibility assessments for educational facilities (Kusumawati et al., 2024). Nevertheless, this study provides an initial framework for flood risk mitigation and disaster preparedness through susceptibility mapping (Asfaw et al., 2023).

D. CONCLUSION AND SUGGESTION

This study analyzed the spatial distribution of flood Susceptibility in relation to educational facilities in Tangerang City using the Weighted Sum method. The results show that approximately 78.6% of schools in Tangerang City are located in areas with moderate to very high flood risk, particularly in the districts of

Tangerang, Ciledug, and Pinang. The findings confirm that both biophysical and anthropogenic factors strongly influence flood susceptibility in urban areas. Practically, the resulting flood Susceptibility map provides an essential foundation for local governments to integrate flood risk considerations into spatial planning (RTRW and RDTR), urban zoning, and educational facility management.

The applied approach remains static and does not fully accommodate the temporal and hydrodynamic dynamics of flooding. The future research may integrate dynamic hydrological models and micro-drainage network data to enhance the precision of flood susceptibility assessments. Moreover, the adoption of more objective weighting methods, such as the Analytic Hierarchy Process (AHP) or Machine Learning approaches, can improve the robustness of spatial analysis results. Overall, this study has contributed to enhancing the weight sum method, which can be used for tropical metropolian area effectively. Futhermore, a significant contribution to flood mitigation efforts to protect educational infrastructure and support resilient urban planning against disasters.

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