doi: 10.37905/jgeosrev.v8i2.37870 ejurnal.ung.ac.id/index.php/jgeosrev

Vol. 8, No. 2, July 2026: 251-262

Jambura Geoscience Review

p-ISSN 2623-0682 | e-ISSN 2656-0380

Department of Earth Science and Technology, Universitas Negeri Gorontalo

GIS-Based Flood Hazard Mapping Using Weighted Overlay in Bekasi City

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ARTICLE INFO

Article history:
Received: 18 March 2026
Accepted: 27 June 2026
Published: 03 July 2026

Keywords:
Bekasi City; Flood Hazard; GIS; Weighted Overlay

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ABSTRACT

Flooding remains a recurrent urban hazard in Bekasi City owing to the interaction of lowland topography, downstream hydrological position, rapid urban development, and reduced surface infiltration. This study aims to map flood hazard levels in Bekasi City using a geographically weighted overlay (GIS)-based method and to examine the spatial agreement between the modeled hazard zones and observed flood occurrences. Seven parameters were integrated into the analysis: land use/land cover, rainfall, slope, soil type, Topographic Wetness Index, distance to rivers, and distance to roads. Each parameter was standardized, scored, and weighted based on relevant literature before being combined to produce a composite flood hazard index. The resulting map classified the study area into very low, low, moderate, high, and very high hazard classes. The results show that more than 80% of Bekasi City is located within moderate to very high flood hazard classes, with higher hazard zones concentrated mainly in the central and eastern parts of the city. These areas are characterized by flat terrain, high wetness potential, proximity to river networks, and a dominant built-up land cover. A preliminary spatial validation using 12 observed flood occurrence points indicates that approximately 83% of the points are located within moderate to very high hazard zones. These findings suggest that the GIS-based weighted overlay method can support preliminary flood hazard identification in data-limited urban areas. However, the results remain sensitive to parameter selection, weighting schemes, and limited validation data.

How to cite: Adzkia, LN. (2026). GIS-Based Flood Hazard Mapping Using Weighted Overlay in Bekasi City. *Jambura Geoscience Review,8*(2), 251-262. https://doi.org/10.37905/jgeosrev.v8i2.37870

1. INTRODUCTION

Flooding is a natural disaster that occurs when water overflows and inundates normally dry areas. It affects a significant portion of the world's population and causes extensive social, economic, and environmental impacts (Teku et al., 2026; Fawwaz et al., 2021). Increased climate variability, particularly the growing frequency of extreme rainfall, heightens the risk of flooding in various regions (Hoq et al., 2021). This is especially true in areas experiencing rapid land-use changes, population growth, and environmental degradation (Balgah et al., 2023). Indonesia, a tropical country with a strategic location, is experiencing significant changes in its rainy-season patterns (Alfarisi Handifa et al., 2023). Over the past few decades, land-use dynamics in Indonesia have undergone rapid changes, increasing flood hazards (Ridwan & Sarjito, 2024). West Java Province is known to have the highest frequency of natural disasters in Indonesia, with a total of 37 incidents, predominantly flood-related. This situation is also felt in the city of Bekasi, where the onset of the rainy season frequently triggers public concern regarding the recurring hazard of flooding. Areas with relatively low elevations and surface configurations that form natural basins have a greater tendency for surface runoff accumulation and for water capacity exceeding the river's carrying capacity, which also contributes to flooding (Dwi Arvi et al., 2025). Hydrologically, the Bekasi City area lies downstream of several river basins, including Cikeas, Cileungsi, and Bekasi. The interaction between lowland topography, downstream hydrological position, and degraded environmental conditions increases flood hazards in Bekasi City.

Flooding is the third-largest contributor to the total economic losses caused by all natural phenomena. In 2025, economic losses in Bekasi City are estimated to be Rp 878.6 billion (Lubis & Riza, 2024; BNPB, 2025). The escalation of flooding not only triggers massive economic degradation but also leads to profound social consequences and health disruptions (Romali et al., 2025). Spatial analysis utilizing remote sensing technology enables the effective identification and analysis of various surface conditions to determine flood hazard levels. The spatially identified affected areas are a top priority to reduce negative impacts and mitigate damage escalation caused by flood events (Pham et al., 2021). The accurate identification of flood-prone zones is an essential preventive measure to optimize flood control (Mokhtari et al., 2024). Therefore, a spatially explicit flood hazard assessment is necessary to support mitigation planning, land-use control, and disaster risk reduction in rapidly urbanizing areas, such as Bekasi City.

This study employs a spatial analysis methodology focused on processing a series of parameters. Hazard analysis was conducted by considering several key parameters, namely, distance from rivers and roads, rainfall, land use/land cover (LULC), soil type, as well as elevation and slope conditions (Almouctar et al., 2024; Kourgialas & Karatzas, 2011). Several quantitative statistical methods are used to assess flood hazards, such as the analytical hierarchy process (AHP), fuzzy analytical hierarchy process (FAHP), frequency ratio (FR), and weighted overlay. The AHP and FAHP methods can still be applied in areas with limited data or where complete records of flood events are unavailable. The FR method can accurately predict flood hazards if complete historical records of flood events are available. However, the availability of complete and spatially accurate flood inventory data remains a common limitation in urban flood studies, making GIS-based multi-parameter approaches important for preliminary flood hazard mapping.

The approaches used in this study were selected because they can systematically integrate various flood-causing parameters in the form of spatial data by assigning scores and weights according to the influence level of each parameter. Weighted overlay is considered effective in flood hazard mapping because it offers high flexibility in integrating various environmental parameters into a single spatial model (Muhammad et al., 2025; Alharbi, 2024). This method can be easily applied to raster data from various sources, thereby simplifying the data analysis and processing workflow (Nainggolan et al., 2024; Rahmanita & Idarwati, 2025). Although the weighted overlay method is widely used in flood hazard mapping, this approach has several limitations, particularly that the determination of weights and scores for each parameter is highly dependent on the subjectivity of expert opinions (Hariyanto et al., 2023; Juliansyah et al., 2026). Accordingly, the use of weighted overlay in flood hazard mapping requires a clear justification of parameter selection, scoring, and weighting procedures to avoid overestimating the reliability of the resulting hazard map.

Previous studies have demonstrated the usefulness of GIS-based flood hazard mapping; however, the application of weighted overlay in rapidly urbanizing downstream cities still requires further evaluation, particularly through comparison with observed flood occurrence data. In Bekasi City, recurrent flooding is influenced by the combined effects of topography, hydrology, rainfall, land-use change, and urban infrastructure. However, limited attention has been given to integrating these parameters into a single spatial hazard model and examining its agreement with observed flood locations. This condition indicates a research gap in the spatial assessment of flood hazards in Bekasi City using a GIS-based weighted overlay approach, supported by preliminary validation.

This study aims to map flood hazard levels in Bekasi City using a geographically weighted overlay (GIS) method by integrating various physical and environmental parameters that influence flood events. Additionally, this study aims to evaluate the spatial agreement of the mapping results through a preliminary validation process by comparing the generated flood hazard map with observed flood occurrence points obtained from secondary sources. The novelty of this study lies in the integration of seven flood-related spatial parameters and the preliminary evaluation of modeled hazard classes using observed flood occurrence points in Bekasi City. The scope of this study is limited to flood hazard mapping and spatial agreement assessment; therefore, it does not assess flood vulnerability, exposure, or risk.

2. METHOD

2.1. Study Area

The study area is shown in Figure 1. Astronomically, this region is located at coordinates 106°48’28’’–107°27’29’’ East Longitude and 6°10’6’’–6°30’6’’ South Latitude. Geographically, Bekasi City is situated in a lowland urban area adjacent to the national economic growth center of Jakarta, making it strategically important but also highly exposed to flood-related hazards. The boundaries of the City of Bekasi include Bekasi Regency to the north and east, the Special Capital Region of Jakarta to the west, and Bogor Regency and Depok City to the south. Administratively, Bekasi City covers an area of approximately 210.49 km² and comprises 12 subdistricts. Bekasi City is also a flood-prone area within the Jabodetabek region.

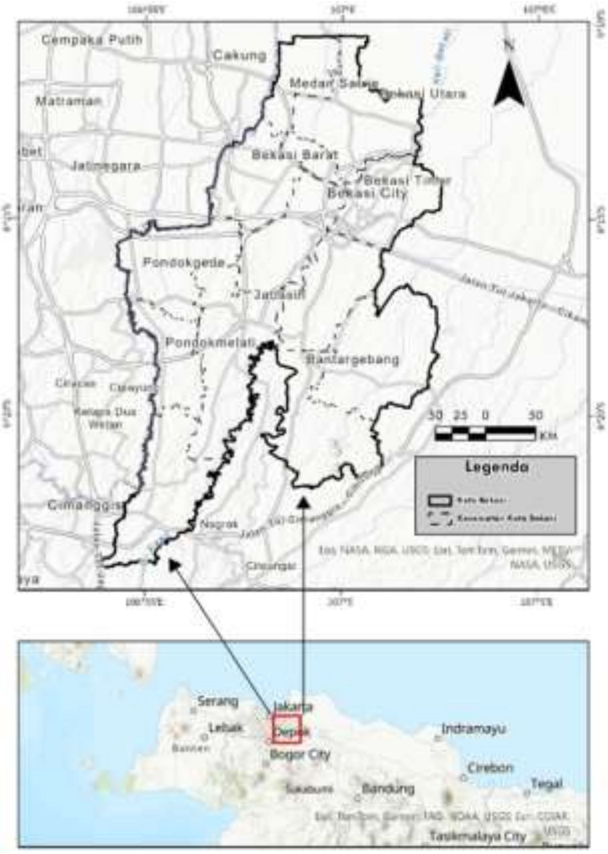

Figure 1. Map of the study area

2.2. Data Collection

This study utilized multiple spatial datasets representing key factors influencing flood hazards. Land use/land cover (LULC) data were derived from Sentinel-2 imagery with a spatial resolution of 10 m. The imagery was acquired between June and August 2025 to minimize cloud cover. LULC classification was used to represent recent surface cover conditions in Bekasi City and to identify built-up areas, vegetation, bare land, cropland, grassland, wetlands, and water bodies. The classification accuracy was evaluated using a confusion matrix based on reference samples collected through visual interpretation of high-resolution imagery. A total of 120 validation samples were used, which were distributed proportionally across all LULC classes. The results showed an overall accuracy of 87.5% and a kappa coefficient of 0.84, indicating a strong level of agreement between the classified map and reference data.

Rainfall data were obtained from the CHIRPS dataset with a spatial resolution of 0.05° and daily temporal resolution. The daily rainfall data for 2025 were aggregated into annual rainfall values to represent the spatial distribution of rainfall intensity, which influences flood hazards in the study area. Topographic parameters, including slope and Topographic Wetness Index (TWI), were derived from DEMNAS with a spatial resolution of 8 m provided by the Geospatial Information Agency (BIG). Distance to rivers and roads was generated using Euclidean distance analysis based on vector data from the Indonesian Topographic Map (RBI). All spatial datasets were projected into a uniform coordinate system, World Geodetic System 1984 / UTM Zone 48S, and resampled to a consistent spatial resolution to ensure compatibility in the raster-based analysis. Data preprocessing, including clipping, reclassification, and raster conversion, was performed using ArcGIS Pro.

2.3. Methodology

The weighted overlay method is a spatial analysis approach that combines several thematic maps representing factors influencing hazard assessments (Adininggar et al., 2016). In this study, flood hazard assessment was conducted using a multicriteria weighting technique that integrates various key variables affecting flood hazards (Muhammad et al., 2025). Each parameter was first standardized and reclassified into five hazard contribution classes, with scores ranging from 1 to 5. A score of 1 represents the lowest contribution to flood hazards, whereas a score of 5 represents the highest contribution. Subsequently, each parameter was assigned a weight based on prior literature reviews to reflect its relative influence in flood hazard analysis.

Parameter weights were determined using a literature-based synthesis approach. Previous studies on GIS-based flood hazard mapping were reviewed to identify commonly used parameters and their corresponding weight ranges. The selected weights were then compared across relevant studies and adjusted conceptually according to the physical and urban characteristics of Bekasi City, particularly its lowland topography, downstream hydrological position, dense built-up areas, and recurrent flood occurrence. These values were used to establish a consistent weighting framework for the weighted overlay analysis.

In flood hazard mapping, the weighted overlay method is widely used because it can accommodate the physical characteristics of a region. These parameters are normalized into scores so they have a uniform scale, allowing the spatial integration process to be conducted objectively. The overlay process is performed on several raster datasets using a uniform measurement scale, where each parameter is assigned a weight according to its level of importance. The final flood hazard index was obtained by summing the multiplication results between each parameter score and its respective weight. The resulting index was then classified into five flood hazard classes: very low, low, moderate, high, and very high.

2.4. Parameter Analysis

Seven parameters were selected based on their relevance to flood hazards: land use/land cover, rainfall, slope, soil type, Topographic Wetness Index (TWI), distance to rivers, and distance to roads. Each parameter was classified into several categories and assigned a score ranging from 1, representing the lowest contribution to flood hazard, to 5, representing the highest contribution. The scoring scheme was developed based on previous studies and adjusted to reflect the physical characteristics of the study area. For example, built-up areas were assigned higher scores because of their low infiltration capacity, whereas steeper slopes were assigned lower scores because of their reduced water accumulation potential. The classification and scoring scheme for land use and land cover are presented in Table 1, where built-up areas and impervious surfaces are associated with higher flood hazards than vegetated or permeable areas.

Land use and land cover (LULC) derived from Sentinel-2 imagery were analyzed to assess their influence on infiltration and surface runoff. The LULC scoring scheme is presented in Table 1. Built-up areas and impervious surfaces were assigned higher scores because they reduce infiltration and increase surface runoff, whereas vegetated areas were assigned lower scores because they support infiltration and water retention. LULC was assigned a weight of 20% and is considered a key parameter influencing flood hazards, as built-up areas reduce infiltration capacity and increase surface runoff in urban environments such as Bekasi City.

Table 1. LULC Parameters

Parameter	Classification	Weight (%)	Scoring
Land Use Land Cover (LULC)	Built Up Area, Wetland, Water Body	20	5
	Bare Land		4
	Crop Land		3
	Grassland		2
	Trees		1

Source: (Park & Lee, 2024)

The distance-to-road parameter was derived using Euclidean distance and classified into ranges reflecting its influence on surface runoff, as summarized in Table 2. Assigned a weight of 10%, this parameter represents anthropogenic effects, in which impervious road surfaces contribute to runoff concentration but have a relatively lower influence than natural hydrological factors.

Table 2. Distance From Road

Parameter	Classification	Weight (%)	Scoring
Distance From Road	<25 meters	10	5
	26–50 meters		4
	51–100 meters		3
	101–150 meters		2
	>150 meters		1

Source: (Swain et al., 2020)

The distance to river parameter was derived using Euclidean distance and classified based on its influence on flood occurrence, as presented in Table 3. A proximity to rivers weighting of 10% increased exposure to overflow during peak discharge events.

Table 3. Distance From River

Parameter	Classification	Weight (%)	Scoring
Distance From River	<50 meters	10	5
	51–100 meters		4
	101–250 meters		3
	251–500 meters		2
	>500 meters		1

The Topographic Wetness Index (TWI) was derived from DEM data to represent the spatial distribution of potential soil moisture and water accumulation. The TWI was calculated using Equation (1).

$$TWI = \text{In} \frac{As}{\tan \beta} \quad (1)$$

where TWI represents the topographic wetness index, As is the upslope contributing area per unit width (m^2/m), and β is the local slope angle in radians. Higher TWI values indicate a greater potential for water accumulation. Therefore, higher TWI values were assigned higher scores in the flood hazard analysis, as summarized in Table 4. The TWI was assigned a weight of 20%, reflecting its strong influence on water accumulation, controlled by both slope and upslope contributing area.

Table 4. Topographic Wetness Indeks

Parameter	Classification	Weight (%)	Scoring
Topographic Wetness Index	-4.33 - -1.44	20	1
	- 1.43 - -0.08		2
	-0.07 – 1.39		3
	1.4 – 3.57		4
	3.8 - 10.7		5

Rainfall data were classified into intensity ranges and assigned scores based on their influence on flood hazards, as presented in Table 5. With a weight of 15%, rainfall acts as the primary triggering factor, in which higher intensity increases surface runoff and contributes to the exceedance of drainage and river capacity.

Table 5. Rain Fall

Parameter	Classification	Weight (%)	Scoring
Rain Fall	< 2000	15	1
	2001–2500		2
	2501–3000		3
	3001-3500		4
	> 3500		5

The soil type was analyzed to evaluate its influence on flood hazards, particularly in terms of infiltration capacity and water-retention characteristics. The classification and scoring of soil types used in this study are shown in Table 6. Soil type was assigned a weight of 10% because it affects infiltration and water-retention capacity. Low-permeability soils were assigned higher scores because they contribute to higher runoff and flood potential.

Table 6. Soil Type

Parameter	Classification	Weight (%)	Scoring
Soil Type	Alluvial, Planosol, Gray Hydromorphic, Lateritic Groundwater	10	5
	Latosol		4
	Mediterranean Soil, Brown Forest Soil		3
	Andosol, Lateritic, Grumusol, Podsol, Podsolik		2
	Regosol, Litosol, Organosol, Renzina		1

The slope was analyzed to evaluate its effect on runoff and water accumulation. Lower slopes tend to increase flood hazards. The classification and scoring results are presented in Table 7. The slope was assigned a weight of 15% because it controls runoff velocity and water accumulation. Flatter areas tend to retain water for longer periods, thereby increasing flood hazards.

Table 7. Slope

Parameter	Classification	Weight (%)	Scoring
Slope	<8%	15	5
	8–15%		4
	15–25%		3
	25–40%		2
	>40%		1

The spatial parameters used in the flood hazard analysis are presented in Figure 2. These parameters were selected based on their relevance to flood occurrence and their ability to represent the physical and anthropogenic factors influencing flood hazards in urban environments. The dataset included land use/land cover (LULC), distance from roads, distance from rivers, Topographic Wetness Index (TWI), rainfall, soil type, and slope. Each parameter was processed, classified, and subsequently assigned scores and weights according to its relative contribution to flood hazards. The spatial distribution of these parameters provides an important basis for understanding variations in flood hazards across Bekasi City and serves as the primary input for the weighted overlay analysis.

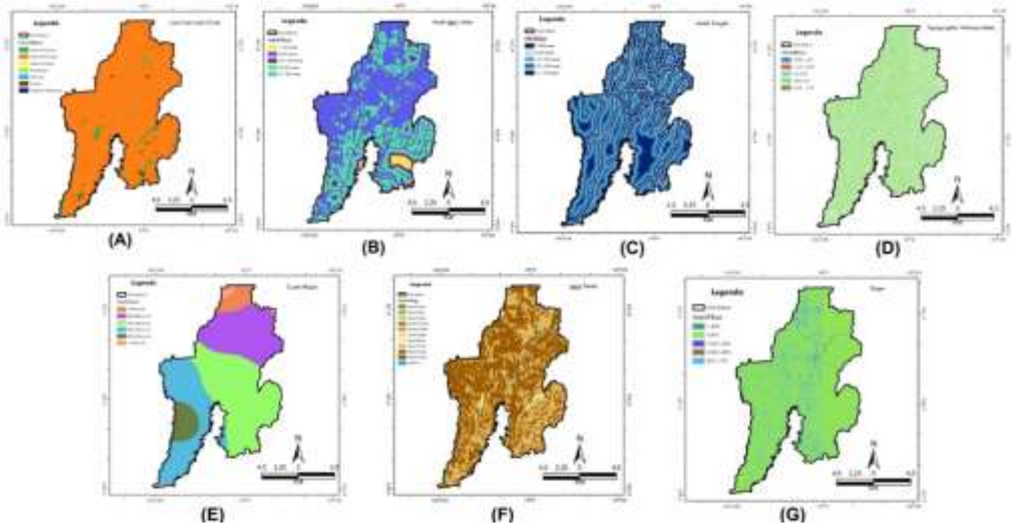

Figure 2. Parameter Data: (A) Land use land cover, (B) Distance from Road, (C) Distance from River, (D) Topographic Wetness Index, (E) Rain Fall, (F) Types of Soil, (G) Slope

2.5. Equation

Flood hazard scoring and spatial analysis were performed using the weighted overlay method, which integrates multiple parameters into a single composite index. The weighted sum approach is commonly used in GIS-based multicriteria decision analysis because it enables several spatial criteria to be combined through standardized scores and relative weights (Malczewski, 1999). Each parameter was assigned a weight based on its relative importance, and individual classes within each parameter were assigned scores reflecting their contribution to flood susceptibility..

$$FHI = \sum_{i=1}^{n} (W_i \ X \ S_i) \tag{2}$$

where Si represents the composite score at the I th spatial location, wj denotes the relative weight of the j th criterion, and xij indicates the normalized value of the j th criterion at the I th location (Malczewski, 1999). The weighted sum method has several advantages, including its simplicity in computation and ease of interpretation, as well as its ability to integrate various types of raster data (Malczewski, 1999). However, it assumes that all criteria contribute in a linear and additive manner, which may neglect potential interactions among variables.

3. RESULTS AND DISCUSSION

3.1. Results

A flood hazard analysis using the weighted overlay method reveals clear spatial variations across Bekasi City. The resulting flood hazard map classifies the study area into five categories: very low, low, moderate, high, and very high hazard levels. The results indicate that more than 80% of the total area falls within the moderate to very high hazard classes, highlighting the widespread exposure of the city to flood-related hazards.

High- to very-high flood hazard zones are concentrated in the central and eastern parts of Bekasi City, particularly in Jatiasih, Jatisampurna, Pondokmelati, and Mustikajaya. This spatial pattern closely corresponds with the distribution of several control parameters, as shown in Figure 2. Areas characterized by high Topographic Wetness Index values (Figure 2D), low slope gradients (Figure 2G), proximity to river networks (Figure 2C), and dominant built-up land cover (Figure 2A) tend to exhibit higher flood hazard levels. These conditions promote water accumulation and reduce drainage efficiency, indicating that the observed pattern is controlled by topographic and hydrological factors rather than occurring randomly.

In addition, the dominance of built-up land use in these subdistricts significantly contributes to increased flood hazards. Impervious surfaces limit infiltration capacity and accelerate surface runoff, thereby intensifying flood potential during high-rainfall events. The presence of dense road networks further exacerbates this condition by increasing runoff connectivity and reducing natural water retention.

In contrast, areas with low flood hazards are mainly located in the southwestern part of Bekasi City, including parts of Medan Satria and West Bekasi. These areas tend to have relatively higher vegetation cover and more permeable surfaces, which enhance infiltration and reduce surface runoff. This contrast demonstrates the strong influence of land use and topographic conditions on the spatial distribution of flood hazards (Swain et al., 2020).

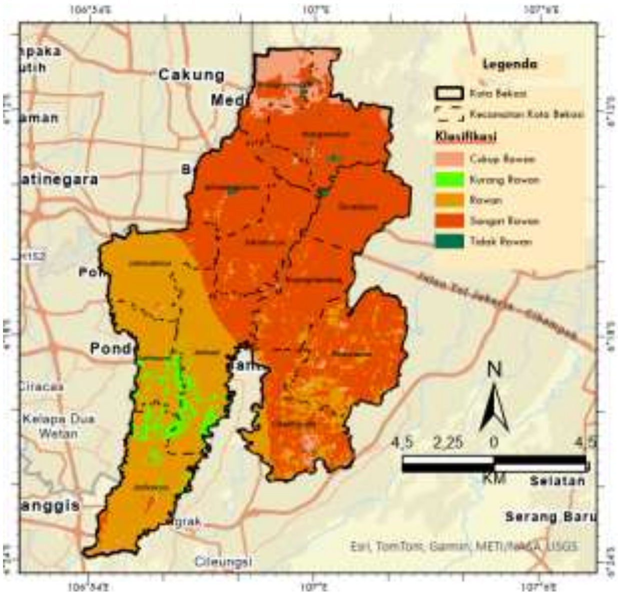

Figure 3. Map of Flood Hazard Levels in Bekasi City

A quantitative analysis of flood hazard classes further supports the spatial pattern observed. The very high hazard class covers approximately 44.2% of the total area, followed by the moderate hazard class at 37.6%. Meanwhile, the high, low, and very low hazard classes occupy significantly smaller proportions.

The predominance of moderate to very high flood hazard classes indicates that flood-related hazards are spatially widespread across Bekasi City. This finding reflects the combined influence of natural and anthropogenic factors, including flat topography, urban expansion, reduced infiltration capacity, and proximity of many urban areas to river systems. The concentration of high-hazard zones in urbanized districts suggests that land-use change and infrastructure development play an important role in shaping flood hazard patterns.

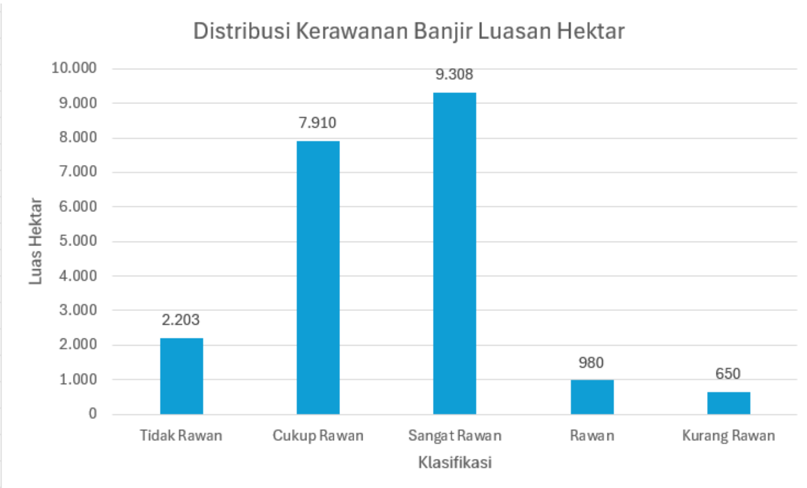

Figure 4. Area distribution of modeled flood hazard classes (hectares) in Bekasi City

A preliminary spatial validation was conducted by comparing the modeled flood hazard map with 12 observed flood occurrence points obtained from secondary flood event reports (Medistiara, 2025). The results show that approximately 83% of the observed flood points fall within moderate-to-very high hazard classes, indicating reasonable spatial correspondence between the model output and observed conditions. However, this validation is limited by the small number of observation points and the use of secondary data sources, which may introduce uncertainty in location accuracy. Therefore, the results should be interpreted as a preliminary assessment rather than a definitive measure of model performance.

Table 8. Coordinate Points of Flood Locations

No	Location	Longitude (X)	Latitude (Y)
1	Gang Mawar	107.0001066	-6.2414510
2	Gang Semar	107.0031108	-6.2390646
3	Kampung Lengkak	107.0257607	-6.2264259
4	Kampung Lebak	106.9785650	-6.2801610
5	Perumahan Bumi Satria	106.9781656	-6.2426992
6	Perumahan Jaka Kencana	106.9769689	-6.2756113
7	Perumahan Depnaker	106.9787851	-6.2732429
8	Perumahan Mayanggi Pratama	107.0118425	-6.2870750
9	Perumahan Mutiara Gading	107.0271032	-6.2824394
10	Perumahan Harapan Baru	107.0167606	-6.3052197
11	Perumahan Pondok Hijau Permai	107.0136371	-6.2637114
12	Taman Narogong Indah	107.0082232	-6.2763206

3.2. Discussion

The findings of this study are consistent with previous GIS-based weighted overlay research on urban flood mapping. Studies in Malang City have shown that combining physical parameters, such as elevation, slope, soil type, rainfall, and land use, can effectively identify flood hazard patterns, particularly in densely populated areas with high to very high hazard levels. Similar results were also found in Semarang City, where the overlay scoring method was effective in identifying flood-prone zones strongly correlated with low-lying areas and proximity to river channels.

In the context of metropolitan areas, research in the Jabodetabek region indicates that integrating additional parameters, such as vegetation indices and the topographic wetness index (TWI), can enhance flood hazard analysis, particularly in urban areas facing high development pressure. Another study in Central Sulawesi confirmed that the weighted overlay method is effective for mapping flood hazards despite limitations related to subjective parameter weighting and highlighted its usefulness for supporting mitigation priorities and spatial planning (Hutauruk et al., 2020).

The research findings in Bekasi City reinforce these results, showing that the prevalence of flood hazard classes is dominated by moderate-to-very high hazard levels, which are closely linked to the contribution of each parameter used in the analysis. Land use and land cover (LULC) have a significant influence, primarily because of the dominance of built-up areas and extensive road networks, which reduce soil infiltration capacity and increase surface runoff (Ali et al., 2025). Regarding soil type, the presence of low-permeability soils increases the potential for surface water accumulation and prolongs flood duration (Beven et al., 1979). Rainfall acts as the primary triggering factor for flooding events, particularly when high rainfall intensity occurs in areas with limited drainage systems (Hoq et al., 2021).

Meanwhile, the relatively flat slope gradients across most of Bekasi City slow surface runoff and increase the likelihood of water accumulation. This condition is further strengthened by the occurrence of high TWI values in several parts of the city, indicating a strong tendency for moisture concentration and water accumulation due to topographic controls and upslope contributing areas (Beven & Kirkby, 1979). The concentration of high-hazard classes observed in Figure 3 is therefore not controlled by a single parameter but rather by the interaction between topography, hydrology, rainfall characteristics, land cover conditions, and urban infrastructure.

The distance from rivers also plays a critical role in determining flood hazards, as areas closer to river channels are more susceptible to overflow during peak discharge events. Similarly, the distance from roads contributes to increased flood hazards because impervious road surfaces increase runoff generation and may reduce the effectiveness of urban drainage systems when not properly managed.

The preliminary validation results further support the reliability of the generated flood hazard map. Approximately 83% of the observed flood occurrence points were located within moderate-to-very high hazard classes, indicating a reasonable agreement between the modeled hazard conditions and observed flood events. Although this level of agreement should not be interpreted as a formal accuracy assessment, it provides preliminary evidence that the selected parameters and weighting scheme can capture the dominant spatial characteristics associated with flood occurrence in Bekasi City.

However, the results remain subject to uncertainty owing to the weighting scheme and classification thresholds applied in the analysis. The weighted overlay method assumes a linear and additive relationship among parameters, which may oversimplify complex hydrological processes. In addition, reliance on a single-year rainfall dataset and limited validation data may affect the robustness of the model. Furthermore, the literature-based weighting approach inherently involves expert judgment and may introduce bias into the final hazard classification.

Despite these limitations, this study demonstrates that GIS-based weighted overlay analysis provides a practical and effective framework for identifying flood hazard patterns in data-limited urban environments. The resulting flood hazard map can support spatial planning, disaster mitigation, infrastructure development, and flood management strategies in Bekasi City. Future studies are recommended to incorporate multi-temporal rainfall datasets, larger flood inventories, and hydrological or hydraulic modeling approaches to improve the predictive capability and reduce uncertainty in flood hazard assessments..

4. CONCLUSIONS

This study mapped the spatial distribution of flood hazards in Bekasi City using a geographic information system (GIS)-based weighted overlay method by integrating seven key environmental parameters. The results indicate that more than 80% of the study area falls within the moderate to very high flood hazard classes, with the highest hazard levels concentrated in the central and eastern parts of the city, particularly in Jatiasih, Jatisampurna, Pondokmelati, and Mustikajaya. The spatial pattern of flood hazards is strongly influenced by the interaction of physical and anthropogenic factors, including flat topography, proximity to river networks, high topographic wetness index (TWI) values, dominant built-up land use, and limited infiltration capacity. These conditions contribute to increased surface runoff and water accumulation, thereby elevating flood hazard levels in urban areas.

The preliminary spatial validation shows that most observed flood occurrence points are located within moderate-to-very high hazard zones, indicating reasonable spatial agreement between the model output and observed flood conditions. However, this result should be interpreted cautiously because the validation was based on a limited number of secondary flood occurrence points and did not include a formal statistical accuracy assessment. Overall, the GIS-based weighted overlay method provides a useful approach for identifying the general spatial pattern of flood hazards in data-limited urban environments. Nevertheless, the resulting hazard map remains sensitive to parameter selection, weighting schemes, and classification thresholds. Future studies should incorporate more extensive flood inventory data, multi-temporal rainfall records, quantitative accuracy assessments, and hydrological or hydraulic modeling to improve the reliability of flood hazard mapping in Bekasi City.

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