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Original Article

Analysis of Flood Disaster Risk Factors with Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) Methods in Bekasi City, West Java, Indonesia

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Abstract *- Typically, flood catastrophes in Bekasi City occur during the rainy season, particularly when persistent heavy rains fall. In addition to the high precipitation factor, numerous additional criteria are used. This research aims to identify the primary factors contributing to flooding in Bekasi City by analyzing the hierarchical process (AHP), determining the fraction of flood-prone regions, mapping them using GIS and AHP spatial analysis, and examining ways to mitigate flood catastrophes. Used the BPMSG process-based AHP analysis to determine the most important precipitation components and the ArcMap overlay function to generate a probability rainfall map for the city of Bekasi. This research utilizes a computerized Bekasi city map, rainfall data, land area data, land use data, population data, and expert opinion. This research investigates the most prevalent causes of flooding, forecasts the possibility of flooding in Bekasi City, and suggests methods for reducing the frequency and severity of flooding. Conclusion: Changes in land use (18.8033%), drainage problems (18.4025%), rainfall patterns (16.9454%), changes in elevation (13.8748%), soil types (12.9074%), population density (9.7221%), waterlogging (9.3445%), and rivers (9.3445%) are the primary causes of bad weather, with extremely high waterlogging levels (area 7.707437 square kilometers or 3.6030160 square miles). Therefore, by developing productive land in Bekasi, the government can reduce the frequency and intensity of floods, reducing slum dwellers. Land planning in conjunction with building standards, infrastructure, and design techniques can significantly reduce the vulnerability of people and urban activities, improvement, deployment, deploy and deepening of various aquifers of water infrastructure systems*.

Keywords *- Bekasi City, AHP, GIS, Flood, Risk.*

1. Introduction

Flood disasters in Bekasi City always come in the rainy season, especially when it rains with high rainfall for a long duration. Floods are the most frequent and destructive hydrological hazard worldwide [1]. From the beginning of 2021 until the beginning of September 2021, Indonesia saw a total of 1,829 catastrophes, most of which were floods (750 instances) and landslides (346 cases) [2]. Floods accounted for 43% of documented natural catastrophes between 1994 and 2013, impacting approximately 2.5 billion people [3]. In the previous two decades, floods have resulted in the deaths of approximately 158 thousand individuals and impacted more than 2.3 billion people to varying degrees. While flood-related fatalities have declined dramatically since the early 1980s, flood-related economic losses are growing [4]. Multiple research projects indicate that population expansion and climate change will substantially exacerbate floods in the future. Subsequent year. [5] [6]

The most important thing is that the flood was local flooding from the Bekasi area itself and consignment flooding from other areas. Through the Bekasi River, then the water volume rose to overflow and flooded the surrounding area. Bekasi River has a great prediction of the possibility of prone areas and floods in the area it crosses. In addition, developments in Bekasi City are identical to developments that cause at least green open land and make Bekasi City prone to flood disasters. The slope of most of the data, changes in land use such that rainwater and air runoff are not absorbed adequately, and soil types that are less susceptible to the passage of air and rainfall at a high pace are physical characteristics that contribute to floods in Bekasi City, average 2000-2500 mm per year.

In addition to urban growth, increased airtight cover, and decreasing forest cover in metropolitan areas, land use/land cover changes are one of the primary factors in floods [7]. The rise of Jakarta influenced Bekasi area development, even becoming part of the Metropolitan JABODETABEK (Jakarta-Bogor-Depok-Tangerang Bekasi), resulting in the fast increase of built-up land in This region. [8]. This happens along with the increasing population, which causes a lot of land cover to change functions into regulation and the lack of air catchment areas in Bekasi City. Another factor that causes flooding in Bekasi is the number of national projects in Bekasi City. The national project strategy is the construction of the Becakayu Toll Road, the Jakarta- Cikampek Elevated Toll Road project, the LRT project, and the Jakarta-Bandung high-speed rail project. These projects have resulted in a few roads being flooded due to the lack of air catchment areas. There may be a connection between human activity and climate disruption, which can occasionally lead to significant rainfall, and the existence of flood spots in places with low and moderate sensitivity [9].

To develop flood effects, it is crucial to have access to dependable data and flood analysis [10]. Flood risk mapping is very important for mitigation and prevention [11]. This may be accomplished via the formulation of disaster reduction policies. As decision-makers, the community and government also benefit from preparing and implementing successful actions [12]. Knowing what factors most influence the flood disaster from each of these parameters will minimize the threat to the people of Bekasi City every time, especially when it rains. Information on areas that have a high vulnerability to flooding must be known so that flood prevention mitigation in the area can be immediately implemented to minimize the potential for flooding.

Developed nations utilizing GIS technology for risk assessments of flood danger [13]. Comprehensive danger information is determined by selecting suitable and acceptable criteria and processing standards and scales (local, regional and national) [14]. The primary benefit of combining GIS-based AHP with a pairwise comparison approach is the ability to generate flexible, updatable, and trustworthy hazard maps [15]. In addition, this approach has been used in various decision-making situations with many criteria due to its ability to integrate vast quantities of heterogeneous data and because it gives a degree of consistency and inconsistency in the produced data. Criteria weightings used to decrease the risk factors it is required to examine the most relevant components and map flood risks to give a wealth of information that is very useful for mitigation and preventative measures [11]. The Analytical Hierarchy Process (AHP) is an efficient way of estimating the degree of flood danger by providing several elements that influence a flooded region. This AHP seeks to evaluate the degree of flood danger by using a Geographic Information System (GIS) with up to 92% accuracy and a validation procedure [16]. Thus, AHP and GIS may be used to generate flood danger maps.

This research aims to: (1) Obtain the dominant factors that caused the flood disaster in Bekasi City by analyzing the hierarchy process (AHP), (2) Knowing the percentage of flood-prone areas and map flood-prone areas in Bekasi City with GIS and AHP spatial analysis, (3) Knowing strategies to minimize flood disasters in Bekasi City. Mapping of flood-prone areas must be considered because it is very important to be an indicator of safety for the community. In addition, environmental education should be emphasized to build shared environmental responsibility. By knowing the magnitude of the factors causing the flood disaster and the flood susceptibility map, it is hoped that it can further help the people of Bekasi City to minimize losses that occur in the future.

2. Literature Review

Several previous researchers have succeeded in producing similar research [4] titled The Mfoundi Watershed at Yaoundé in the Humid Tropical Zone of Cameroon: A Case Study of Urban Flood Susceptibility Mapping. The researcher conducted research on Yaoundé Town, Cameroon's political center, which is located in the humid tropical zone of the southern plateau and is drained by the Mfoundi watershed, which has a surface area of 95,6 km2. There they often experience major floods. Researchers want to get a flood risk analysis in these areas. The parameters analyzed were rainfall, elevation, slope, soil type, geology, and land use, utilizing data sources from topographic maps, soil type maps, geological maps, and BMKG rainfall data. This study is significant for a number of reasons, including the fact that it was conducted in a region where environmental accidents could occur but where there have not been many studies to identify these risks; the fact that it offers a fundamental tool for environmental decision-making for better management of the Mfoundi Watershed; and the fact that it is an experimental study representative of the humid tropical forest zone subject to forcings that should be expanded to larger scales by future research.

AHP-GIS downstream analysis for community flood hazard assessment near a world heritage site on Ayutthaya Island, Thailand, which often experience major floods. Researchers use data sources including Digital Elevation Model (DEM), rainfall data, historical flood data, and land use data [15]. This study maps flood-prone locations on Ayutthaya Island, Thailand, and identifies the main risk factors and issues that cause flooding. Regression analysis also shows that past flood experiences may not necessarily result in the desired proactive action in managing flood risk and its communities.

A multicriteria-based geographic information system (GIS) analysis of flood hazard and risk in Ambo City and its watershed, West Java [17] which often experiences major floods. Researchers want to get a flood risk analysis in these areas. Researchers relied on 2015 Landsat Imagery, a digital map on a shape file at 1: 50,000 scale from the Ethiopian Mapping Authority, and rainfall data (1998–2016) to reach their conclusions. The most salient flood risk factors, risk percentages, and flood zone mapping in Ambo City, Ethiopia, as well as possible policies offered for sustainable flood risk management in urban watersheds, are highlighted. The result is that 50.09% of the watershed area of Ambo City is an area with high to very high flood risk.

Several previous research in the near location was also published in 2015. This article [18] discusses the same topic but with less parameter research, entitled "Multicriteria Analysis and Remote Sensing for Flood Hazard Delineation in Paddy Field Utilization" (Under Case Study of Land Use). Researchers conducted research on the West Java Citarum watershed in the Citarum Downstream Watershed (Purwakarta, Kerawang, and parts of Bekasi Regency) which often experience major floods. Researchers want to get a flood risk analysis in these areas. The parameters analyzed were rainfall, geology, and land use, utilizing data sources from topographic maps, soil type maps, geological maps, and BMKG rainfall data. From the analysis, results obtained the level of vulnerability and causal factors—floods in the Citarum.

3. Materials and Methods

3.1. Description of Study

Bekasi City is situated in Indonesia's West Java region. Geographically, it is situated between 106°48′28″ and 107°27′29″ east longitude and 6°10′6″ and 6°30′6″ south latitude. The watershed's total land area is about 210.13 km2. In 2021, the total population of the watershed will be about 2.56.940 people.

3.2. Methods of Data Collection

Fig. 1 depicts a schematic study diagram. This research employed Digital Elevation Model data from DEMNAS data at a scale of 1:100,000 Jakarta and Karawang sheets (in. tiff format), numerous shapefiles and a digital map of Bekasi City (in. shp format) from the Agency for Geospatial Information Agency (BESAR) (BESAR). 2014-2021 precipitation data from the BMKG and population density data from the Central Statistics Agency (BPS). These data will be handled via a geographic information system. Experts in academics, practitioners, or those with a background in Geology / Geological Engineering, Geophysics / Geophysics Engineering, Environmental Science / Environmental Engineering, Civil Engineering, Geography, the field of Geodesy / Geomatics / Geodesic Engineering and Geomatics, or the field of Urban Area Planning assesses data in addition to processing AHP weighting data. Using real field condition data and the GIS approach, all parameters' degrees of vulnerability will be determined for each. Once the findings are obtained, an overlay map may be produced for all parameters using these results. AHP scoring may also be done concurrently with overlay map development. AHP score results may be processed and computed using BPMSG software. The findings must indicate a consistency level of CR less than 0.1 so that the results may be accepted. After that, all AHP and GIS results are computed. Then, a combination of the GIS approach and the AHP weight computation is carried out. Using the GIS and AHP methodologies, the data may be classed to provide a flood risk map for Bekasi City.

After the risk map is developed, the validity of the map will be checked to determine whether it is acceptable or not with the actual flood circumstances that have been happening in Bekasi City. The validity test material is the DEM from InaRisk BNPB 2015- June 2022. When performing research, it is vital to validate if the findings are unsatisfactory. If the findings match, the created risk map will be laid out, and a GIS and AHP-based flood risk map for Bekasi City will be created. In addition, this report provides recommendations for preventing future flood disasters.

3.3. Methods of Data Analyst

3.3.1. AHP Method

Data processing with the AHP method aims for rank analysis of which factor has the most influence level risk flood in Bekasi City. Data processing is carried out with the use help of the BPMSG application, then conducted weighting factor shaper vulnerable flood in analysis multicriteria using Analytical Hierarchy Process (AHP) method and scoring (scoring) based on the questionnaire from the experts.

Table 1. Nine-point Pairwise comparison scale. Source: [19]

Intensity of Impor-tance	Definition	Explanation
1	Equal Importance	Two elements contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one parameter over
5	Strong Importance	another Experience and judgment strongly favor one parameter over another
7	Very Strong Importance	One parameter is favored very strongly and is considered superior to another; its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favoring one parameter as superior to another is of the highest possible order of affirmation.

Note: 2,4,6,8 can be used to express intermediate values, 1-2, etc., for parameters that are very close in importance

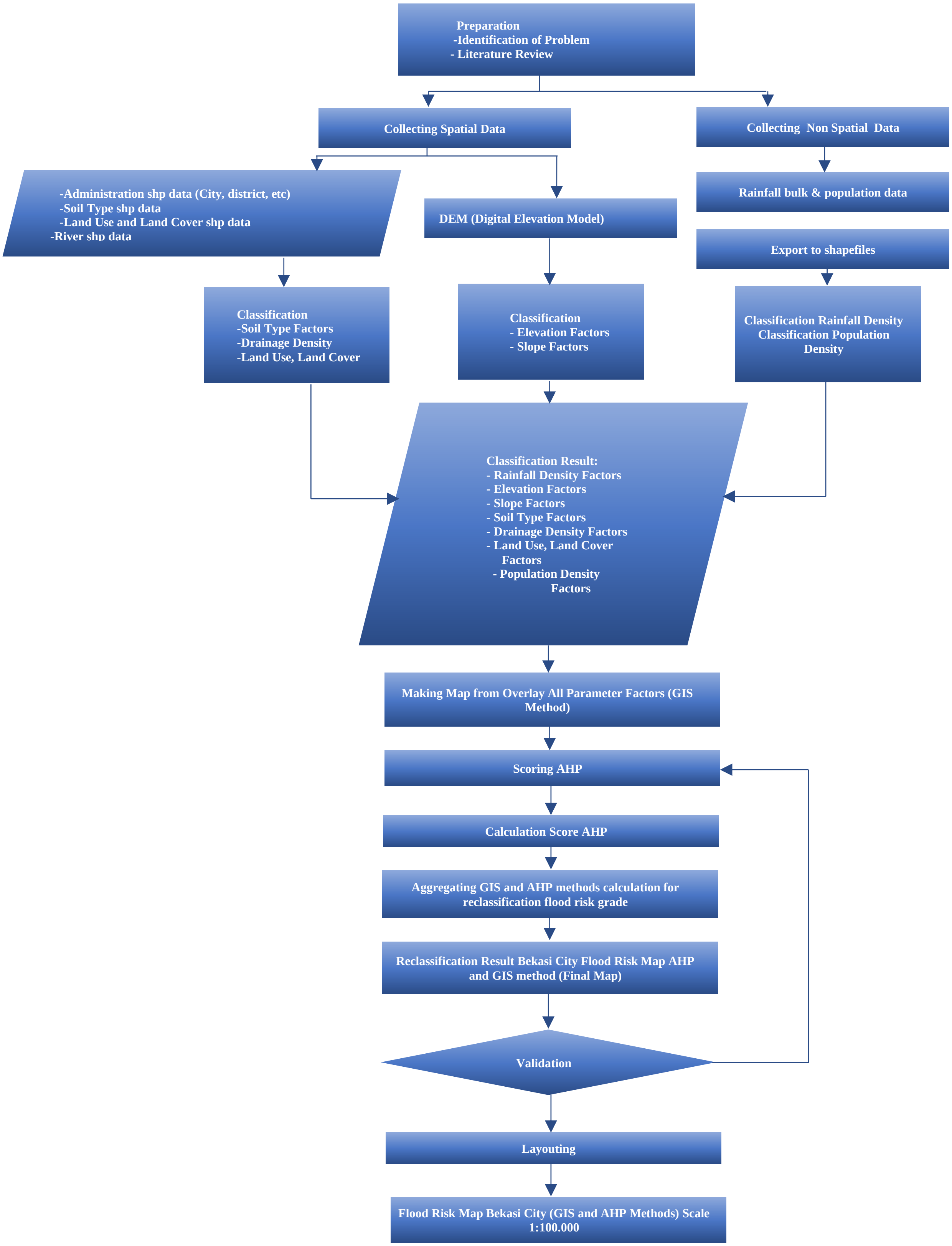

Fig. 1 Schematic Diagram Research

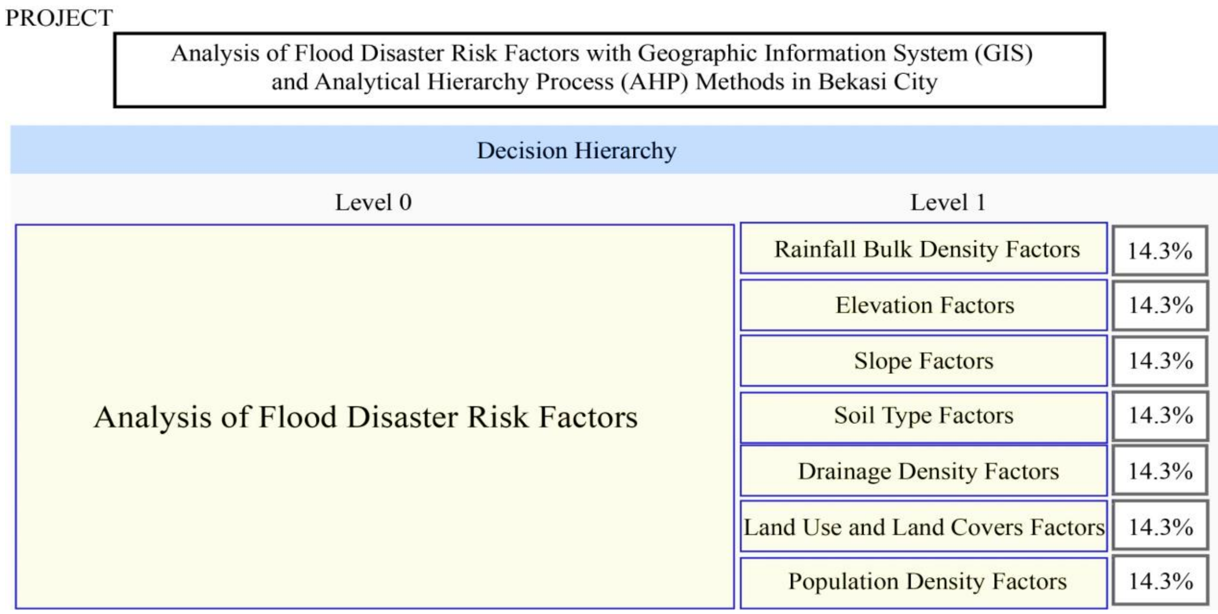

Fig. 2 Decision Hierarchy of Flood Risk Factors

Table 1 shows a nine-point pairwise comparison scale by [19]. Results from the questionnaire were put into the BPMSG (Business Performance Management Singapore) software once they were recorded. Fig. 2 shows the Hierarchy of Flood Risk Factor Decisions. Factors that are thought to affect rain in Bekasi City were tested in the BPMSG software using the same weight of 4.3%.

Using the information provided in the questionnaire, the BPMSG program will generate a matrix-style overview of all the findings Table 1. Following that, not only will the matrix normalization and ranking be shown, but so will the corresponding information. The BPMSG program additionally includes a "column" labeled " data information" for the purpose of notifying the user whether the logical consistency requirements have been met. When a survey's findings do not meet the required level of consistency, the program will suggest a new data source to fill in the blanks. The AHP classification approach is recognized to work once findings from all good parameters, both natural and artificial, have been shown to be consistent with established standards (Table 2). Thereafter, a Pareto chart analysis was performed on the collected data.

3.3.2. Flooding Hazard Factors

Various potential causes of flooding in metropolitan settings, both natural and manmade, will be examined. A collection of methods may be used to convert GIS data into a spatial context. Rainfall, elevation, slope, soil type, drainage density, and porosity are all examples of interfering natural factors. Moreover, between the population density factor and the land use/land cover component, there are non-natural elements.

Rainfall Factor

Rainfall is the quantity of water that falls on the soil's surface during a certain period and is measured in millimeters (mm). One of the primary causes of the flood is the combination of intense rainfall and increased capability for discharging surplus water [16]. When combining this labor with heavier rainfall, the susceptibility to flooding increases. Table 2 is used for categorization in this research.

Elevation Factor

The height is crucial in influencing the movement direction, overflow, and water depth [20]. The elevation is the distance in meters (m) from the ocean's surface to a normal region proclaimed in meters (m) and measured from that area. The elevation of a region has a considerable effect on the spread of flooding. This component interacts with the lower elevation of a location, hence increasing its flood risk. Table 2 is used for categorization in this research.

Slope Factor

The ratio of a thing's steepness or angle of tilt relative to the horizontal plane is its slope [21]. On a higher surface flat, flowing water is slower, gathers longer, and accumulates, making places more susceptible to flooding than those with a steeper slope [20]. The terrain on the lower slope is higher to impact flooding.

Soil Type Factor

Various terrain types have varied capabilities. Increased danger of flooding correlates with a loss in the infiltration capacity of the ground, resulting in an increase in runoff surface. When the rate of water delivery exceeds the ground's infiltration capacity, downslope runoff on sloping terrain may cause floods [16]. Table 2 is used for categorization in this research.

Density Drainage Factor

Density The suggested definition of hydrology as the ratio of long drainage to river area is based on drainage. Density drainage is determined by permeability, erodibility of surface material, vegetation, slope, and time. Function infiltration is the reverse of density drainage. Greater drainage volume and erodible geology reduce the likelihood of floods in a location. Larger runoff from a basin's area is the consequence of greater drainage volume and erodible geology. The formation of sediments on the surface of the soil and accumulation of clay (blockage) can reduce the rate of filtration, biological, chemical, and physical, which will result in continuous flooding [9].

The river's size index density might be calculated using the following formula: (1).

$$Dd = L / A \qquad (1)$$

Description:
Dd : River density index (km/km2)
L : Total River length (km)
A : Watershed Area (DAS) (km2)

Land Use and Land Cover Factor

Use land is produced from land employed for a certain purpose, as is an allotment. Consider this research while evaluating land use. Numerous experts in the field of flood risk management demonstrate that change of use/cover land is a contributor to the primary flood, along with increasing urban development, an increase in waterproof cover, and a decrease in forest cover in the region, resulting in an increase in runoff in cities [7]. Table 2 is used for categorization in this research.

Population Density Factor

The quantity of objects inside a region determines its density. In this unit use unit/area, population density influences the likelihood of floods. High population growth rates need sufficient housing and food, both of which rely on the availability of land. This research uses the following formula (2) and Table 2 for categorization.

$$PD = QP / A \qquad (2)$$

Description:
PD : Density Population
QP : Quantity Population
A : Area

3.3.3. Overlaying All GIS Parameters

The merging/overlapping procedure in ArcView will make use of a geoprocessing extension (intersecting two themes) by integrating several thematic maps in accordance with the previously mentioned flood criteria. Using code block data in ArcGIS, the GIS Overlay process connects directly to the software in the Attribute table through the field calculator option. The outcome will be a map of hazards and vulnerabilities. First, choose Intersect from the Arc Toolbox's menu. Then, input all the parameters created in polygon format. Then, under the Intersect column, click OK. The ArcGIS program will divide regions based on comparable characteristics. Before obtaining the result, two merging steps are performed to assist the overlap process.

3.3.4. Aggregating AHP Scores in GIS

The value of each AHP weight received from the survey findings will be loaded into the ArcGIS program in accordance with the parameters determined for the actual situation. First, enter the criterion score. Then, input the value weight data depending on the AHP. To get the final score, the value to the left of each AHP component is multiplied by the weight of the scoring results for each area and then added together. Table 3 displays one of the areas in Bekasi City with a criterion score based on field findings with the parameters from Table 2, with the results multiplied by the weights from the hierarchical analysis method (AHP). The total score is then determined.

Once the overall score is determined, this number will be included in the flood vulnerability map as a parameter. The final values are then loaded into the ArcGIS program using the field calculator menu and script codes for all parameters to generate a map of flood susceptibility. After determining the overall score, the risk calculation is performed. The following formula may be used to represent risk:

$$\begin{aligned} Risk &= Hazard \times vulnerability \\ &= (H1 + H2 + H3 + H4 + H5) \times (V1 + V2) \end{aligned} \qquad (3)$$

Description:
H1: Rainfall index value
H2: Altitude/Elevation index value
H3 : Slope index value
H4 : Soil Type Index value
H5 : Density index value Drainage
VP1: Land Use Index Value
VP2: Density index value Population

The final assessment is divided into 5 classifications. The classification using the formula highest minus lowest result divided number of parameters. The classification is shown in the table below.

Classification =
(Highest Result - Lowest Result) : Number of Parameters (4)

Based on the result from Formula (4), we know the distance between the classification levels is 35. Then this value will be a parameter that will be included in the flood vulnerability map. The final assessment is divided into 5 classifications. If the result <340 as a very low grade, 24-275 as a low-grade risk, 275-310 as a moderate grade risk, 310-345 as a high-grade risk, >345 as a very high risk. The classification is shown in Table 4 below.

Table 2. Weighted flooding hazard ranking for the watershed.

Parameters and source	Relative Weight	Reclassified Parameter	Ranking	Hazard
Rainfall Factors	14.30%	0-20	1	Very Low
		20-50	2	Low
		50-100	3	Moderate
		100-150	4	High
		>150	5	Very High
Elevation Factors	14.30%	>60	1	Very Low
		45-60	2	Low
		30-45	3	Moderate
		15-30	4	High
		0-15	5	Very High
Slope Factors	14.30%	0-8	1	Very Low
		8-15	2	Low
		15-25	3	Moderate
		25-45	4	High
		>45	5	Very High
Soil Type Factors	14.30%	Cambisols, Litosols, Regosols Renzia,	1	Very low
		Nitisols, Andosol, Grumusol,	2	Low
		Podsolic, Luvisols	3	Moderate
		Latosols, Mediteran, Leptosols	4	High
		Allucial, Plamosols, Hidromorf, Vertisols	5	Very High
Drainage Density	14.30%	0	1	Very Low
		<2.5	2	Low
		2.5-10	3	Moderate
		10-25	4	High
		>25	5	Very High
Land Use/ Land Cover	14.30%	Forest	1	Very low
		Shrubs, Moors, Meadows	2	Low
		Agriculture, Rice Fields, Fields, Gardens	3	Moderate
		Residential, Industry and Warehouse	4	High
		Waters, Rivers, Reservoirs, Swamps, Ponds	5	Very High
Population Density	14.30%	<50	1	Very low
		51-150	2	Low
		151-200	3	Moderate
		201-400	4	High
		201-400	5	Very High

Table 3. Calculation of the total score in the example district in Bekasi City

	Rainfall Density	Elevation	Slope	Soil Type	Drainage Density	Land Use/ Land Cover	Population Density
Score Criteria	2	2	1	4	1	3	1
Weight	16.90%	13.90%	9.30%	12.90%	18.40%	18.80%	9.70%
Total Score	33.8	27.8	9.3	51.6	18.4	56.4	9.7
Result	207						

The final value is then entered into the ArcGIS software to obtain a flood vulnerability map using the field calculator menu with a script code for all parameters at all levels of flood vulnerability. Then, enter the values obtained according to the related parameters. After that, click the Dissolve menu on the Arc Toolbox, then enter the overlay data created in the previous shp.

After that, check the CLASSIFICATION column, then OK. After success, change the color notation according to the classification color.

3.3.5. Validation

The validation process was carried out to test the accuracy of the zoning results for the Bekasi City flood risk map. This validation process was carried out by taking DEM data for the city of Bekasi that occurred from INARisk BNPB and then comparing it with the flood-prone zones that had been created previously using Arc GIS software.

4. Result and Discussion

4.1. Scoring from AHP Method

Prior to determining the weight value of each factor, experts, practitioners, and academics are required to submit their questionnaire replies to the BPMSG software. After data entry, the application will generate a pairwise comparison matrix for each criterion. There are seven factors. Consequently, the output is 7 rows by 7 columns below.

Table 5 shows the recapitulation outcomes questionnaire. A is the precipitation factor. B is the factor of elevation. The slope factor is C. D is the factor for soil type. E represents the Drainage Density Factor. The letter F represents Land Use and Land Cover Factors. G is the abbreviation for Population Density Factor. The results are calculated by dividing the current rows and columns. The sum represents the total of each column. While the results of Table 5 are divided by the total of each column to get Table 6, Table 6 contains the resulting numbers. The priority vector, meanwhile, is the sum of each row. Moreover, the ranking outcomes are achieved by dividing the priority vector by the quantity parameter.

Table 4. Classification of flood vulnerability level criteria

Flood Risk Level in Bekasi City	Score	Colour
Very low	<340	Dark green
Low	241-275	Green
Moderate	275-310	Yellow
High	310-345	Orange
Very high	>345	Red

Table 5. Recapitulation results questionnaire. Source: (Based on Experts'2022).

Consolidated Decision Matrix	A	B	C	D	E	F	G
A	1.0000	1.4000	2.1495	1.2723	0.9137	0.7312	1.6318
B	0.7147	1.0000	1.7575	1.0896	0.8806	0.6414	1.3310
C	0.4652	0.5690	1.0000	0.8033	0.5813	0.5252	1.0000
D	0.7860	0.9178	1.2449	1.0000	0.6805	0.7351	1.4325
E	1.0945	1.1429	1.7204	1.4694	1.0000	1.2501	1.8821
F	1.3750	1.5592	1.9041	1.3603	0.7999	1.0000	1.9225
G	0.6128	0.7513	1.0000	0.6981	0.5313	0.5202	1.0000
Amount	6.0482	7.3401	10.7764	7.6929	5.3873	5.4031	10.2000

Table 6. Weighted Comparison table. Source: (Weighted Comparison Based on Experts'2022)

Consolidated Decision Matrix	A	B	C	D	E	F	G	Priority Vector	Priority Vector/ Quantity parameters
A	0.1653	0.1907	0.1995	0.1654	0.1696	0.1353	0.1600	1.1858	0.1694
B	0.1182	0.1362	0.1631	0.1416	0.1635	0.1187	0.1305	0.9718	0.1388
C	0.0769	0.0775	0.0928	0.1044	0.1079	0.0972	0.0980	0.6548	0.0935
D	0.1300	0.1250	0.1155	0.1300	0.1263	0.1361	0.1404	0.9033	0.1290
E	0.1810	0.1557	0.1596	0.1910	0.1856	0.2314	0.1845	1.2888	0.1841
F	0.2273	0.2124	0.1767	0.1768	0.1485	0.1851	0.1885	1.3153	0.1879
G	0.1013	0.1024	0.0928	0.0907	0.0986	0.0963	0.0980	0.6801	0.0972
Amount	1.00	1.000	1.000	1.000	1.000	1.000	1.0000	70000	1.0000

The natural values are normalized by summing the column values and dividing each cell's value by the total of the column values. It is known that land use (18.8033%), drainage density (18.4025%), rainfall (16.9454%), height (13.8748%), soil type (12.9074%), population density (9.7221%), and slope (9.3445%) are the leading causes of floods. If the CR value is less than 0.10, the results of AHP computations are consistent for decision-making purposes. From these calculations, a CR value of 0.004969 is derived, allowing us to conclude that the AHP calculation findings for this research meet the standards and are consistent.

After validating the data's accuracy, Pareto analysis may be performed. Fig. 3 depicts the BPMSG software-generated data examined using a Pareto chart. The Pareto chart has a dominating value of 80-20, indicating that 80% of the primary causes of flooding in the city of Bekasi stem from land use (18.8033%), drainage density (18.4025%), rainfall (16.9454%), altitude (13.8748%), and soil type (12.9074%).

Table 7. Weighted flooding hazard ranking for the watershed.

Parameters	Relative Weight	Reclassified Parameter	Ranking	Hazard	Result
Rainfall Factors	16.95%	0-20	1	Very Low	48.21%
		20-50	2	Low	26.00%
		50-100	3	Moderate	12.29%
		100-150	4	High	10.64%
		>150	5	Very High	2.87%
Elevation Factors	13.88%	>60	1	Very Low	4.90%
		45-60	2	Low	6.51%
		30-45	3	Moderate	21.62%
		15-30	4	High	32.70%
		0-15	5	Very High	34.27%
Slope Factors	9.35%	0-8	1	Very Low	67.02%
		8-15	2	Low	9.69%
		15-25	3	Moderate	10.05%
		25-45	4	High	9.55%
		>45	5	Very High	3.69%
Soil Type Factors	12.90%	Cambisols, Litosols, Regosols Renzia,	1	Very low	
		Nitisols, Andosol, Grumusol,	2	Low	
		Podsolic, Luvisols	3	Moderate	
		Latosols, Mediteran, Leptosols	4	High	75.15%
		Allucial, Plamosols, Hidromorf, Vertisols	5	Very High	24.84%
Drainage Density	18.40%	0	1	Very Low	
		<2.5	2	Low	
		2.5-10	3	Moderate	2.6
		10-25	4	High	
		>25	5	Very High	
Land Use/ Land Cover	18.80%	Forest	1	Very low	0.51%
		Shrubs, Moors, Meadows	2	Low	8.00%
		Agriculture, Rice Fields, Fields, Gardens	3	Moderate	2.60%
		Residential, Industry and Warehouse	4	High	88.89%
		Waters, Rivers, Reservoirs, Swamps, Ponds	5	Very High	
Population Density	9.72%	<50	1	Very low	0.89%
		51-150	2	Low	69.48%
		151-200	3	Moderate	12.52%
		201-400	4	High	17.11%
		201-400	5	Very High	

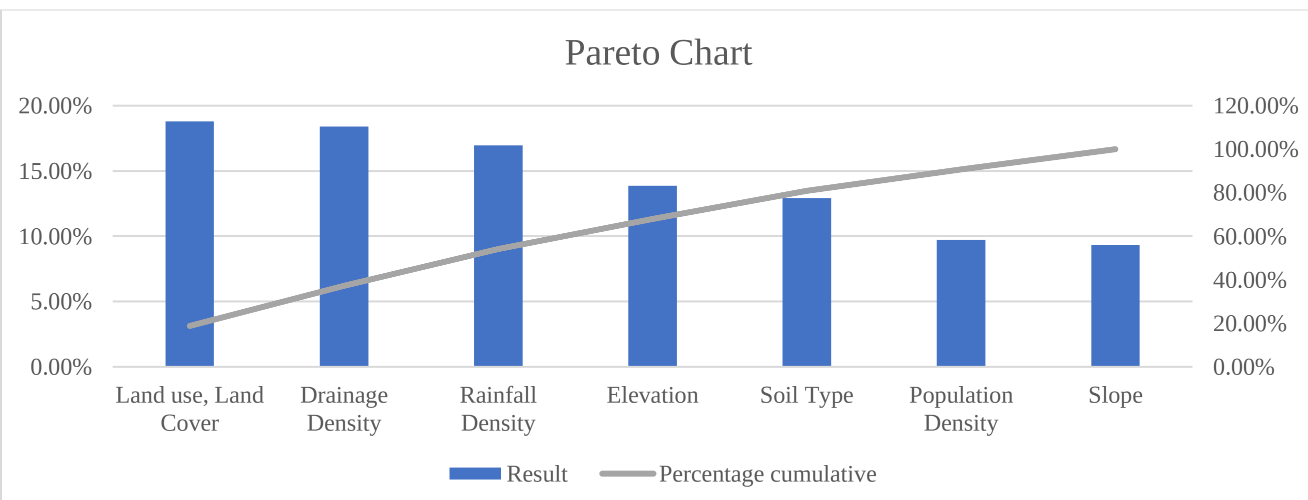

Fig. 3 Pareto Analysis Diagram

From the chart above, based on the concept of Pareto analysis using the 80-20 method, it can be analyzed that the cause of flooding in Bekasi City is the land use factor, with a percentage of 18.8%. However, because the percentage of this land use factor does not exceed 80 percent, it is still within reasonable limits.

Moreover, when reviewing all the existing factors, it can be concluded based on Pareto analysis; the land use factor is 18.8033%, drainage density is 18.4025%, rainfall is 16.9454%, elevation is 13.8748%, soil type is 12.9074% being the dominant cause of flood risk factors in Bekasi.

4.2. Contributing Factors for Flood Hazard

According to statistical data from the BPMSG program, all components might cause flooding in Bekasi City and interact with one another. The results were gained using ArcGIS. Table 7 displays all the results of calculations using the GIS method for all parameters. There are seven characteristics, including rainfall density, elevation, slope, soil type, drainage density, land use and land cover variables, and population density. All of which provide flood risk ratings depending on their categorization.

According to estimates, land usage poses the greatest flood risk in Bekasi City (18.8033%). Fig. 4 displays the Land Use and Land Cover Map. The graphic demonstrates the great danger of flooding in the Bekasi City region caused by homes, industry, and warehouses. This is problematic land use since roughly 88.88% of the Bekasi City area is occupied by settlements. This is the reason why high levels of land use considerations contribute to floods. This is shown by the orange colour dominating the map. The remaining 11.12% consists of woods, an agricultural area, fields, plantations, and bodies of water, shown on the map by the colour red, yellow, light green, and dark green.

The second flood threat in Bekasi City (18.4025%) is attributed to the drainage density. Fig. 5 shows the Drainage Density Factors Map with a river density categorization of "medium" and a value of 2,46677342. This indicates that if the Dd value is low, the river channel will pass over rocks with high resistance, limiting the silt transported by the river flow and making the area more susceptible to floods. This is the reason why the city of Bekasi has a moderate risk of flooding, as shown by the predominance of yellow on the map.

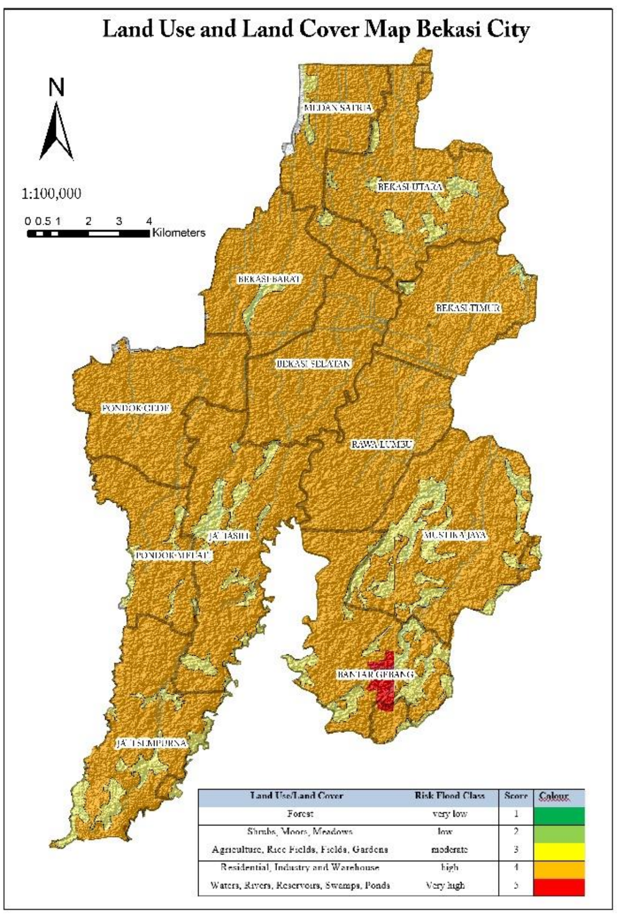

Fig. 4 Land Use and Land Cover Parameter Map.

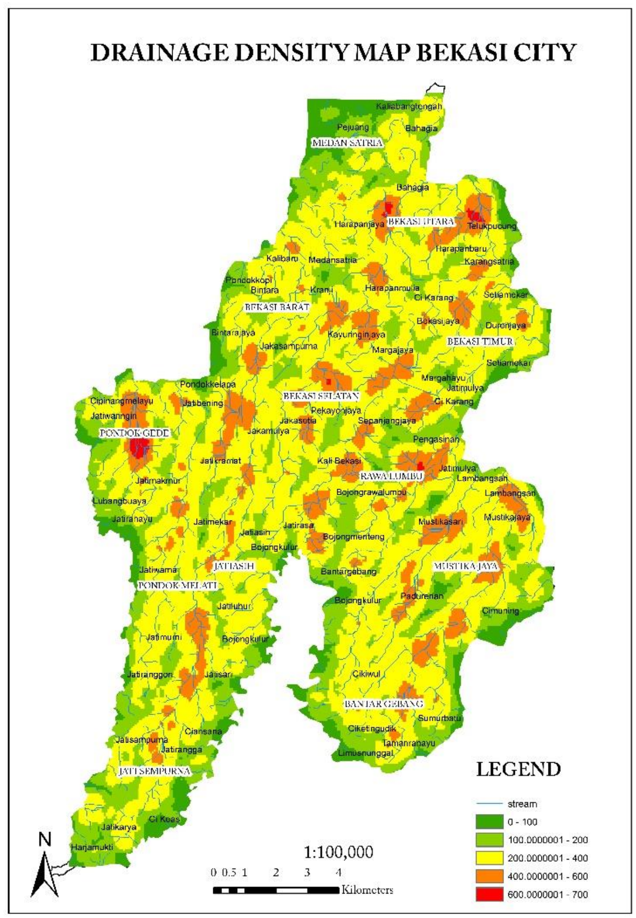

Fig. 5 Drainage Density Parameter Map.

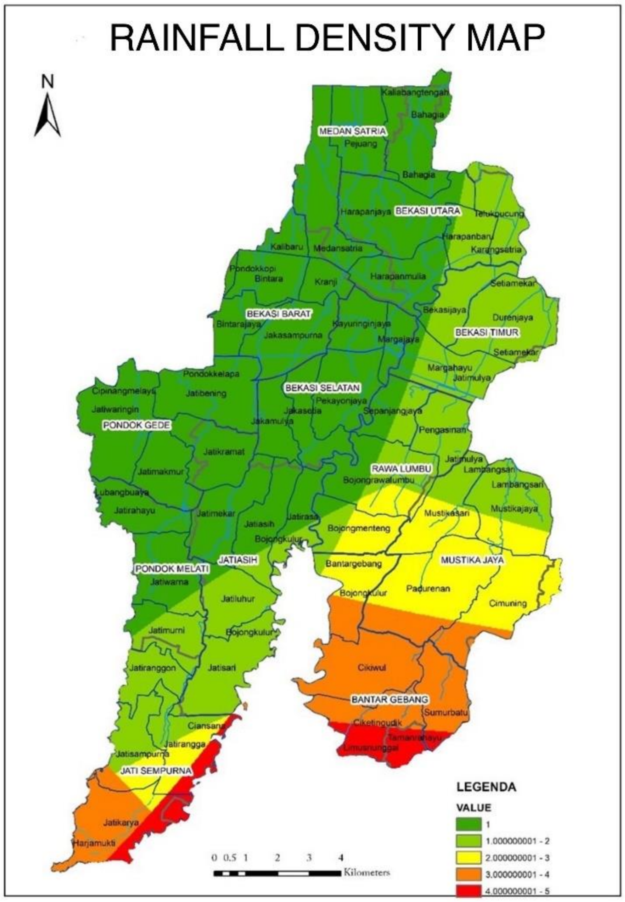

Fig. 6 Rainfall Density Parameter Map

Rainfall is the third most significant factor (16.9454%) in Bekasi floods. A map of Rainfall Factors is shown in Fig. 6. On the map, the district of Jatisampurna is shown in red with a very high degree of flood danger due to very high precipitation (2.86%). In certain regions (10.64%), heavy precipitation will result in a significant flood danger, shown in orange on the map. In certain regions, moderate precipitation (12.29%) will result in a moderate flood danger, shown in yellow on the map. Low precipitation in certain locations (25.99%) will result in a low flood danger, shown on the map in light green. Furthermore, very low precipitation in certain regions (48.2%) will result in a very low flood danger, as seen in dark green on the map.

As one of the four contributing elements to Bekasi City's (13.8748%) danger of flooding, elevation is a factor of four. Fig. 7. depicts the map of elevation factors. As depicted in dark green on the chart, the maximum elevation in the Bekasi City region, more than 60 meters, has a very low flood risk of 4.89 percent. At an elevation of 45 to 60 meters, it has a modest flood risk of 6.51 percent, as seen in light green on the map.

At elevations between 30 and 45 meters, it poses a moderate flood risk of 21.62%, as seen in yellow on the map. At a height between 15 and 30 meters, it poses a 32.69 percent flood risk, as depicted in orange on the map. Furthermore, at a height between 0 and 15, it poses a moderate flood risk of 34.27 percent, as seen in red on the map.

One of the five leading reasons for floods in Bekasi City (12.9074%) is soil type. Fig. 8 depicts a map of Soil Type Factors. 24.84 percent of the soil in Bekasi City consists of Alluvial Fluvisols, which offer a very high risk of flooding and are shown in red on the map. On the map, Nitosols (75.15%) that pose a high danger of flooding are shown in orange.

Bekasi City's population density is one of the six reasons for floods (9.7221%). Fig. 9 shows maps of population density factors. On the map, 17.1% of the population density in Bekasi City has a high risk of flooding, depicted in orange. As depicted in yellow, 12.5% of the population density faces a moderate risk of flooding, and 69.47% of the population density provides a minimal danger of flooding, as shown by the colour light green.

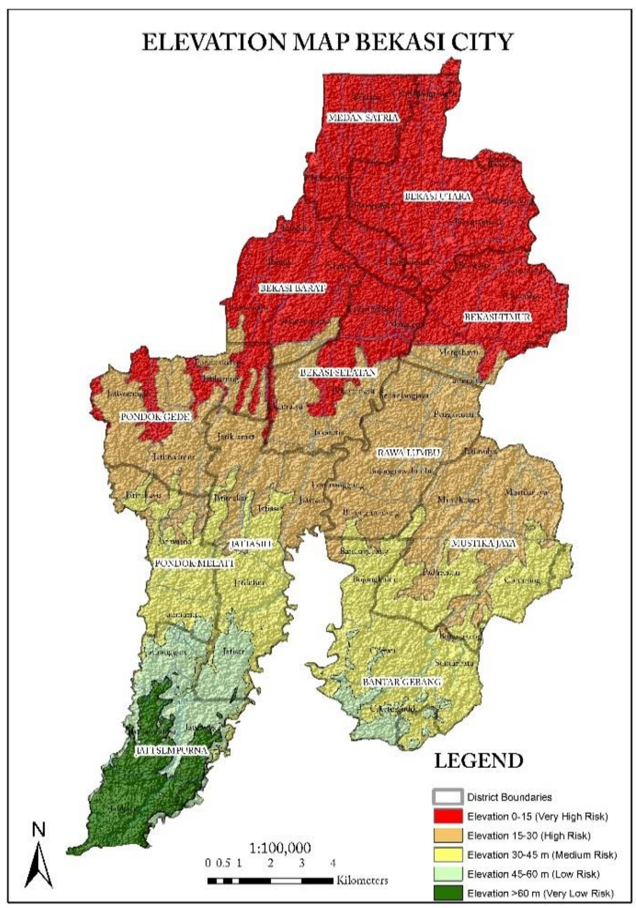

Fig. 7 Elevation Parameter Map

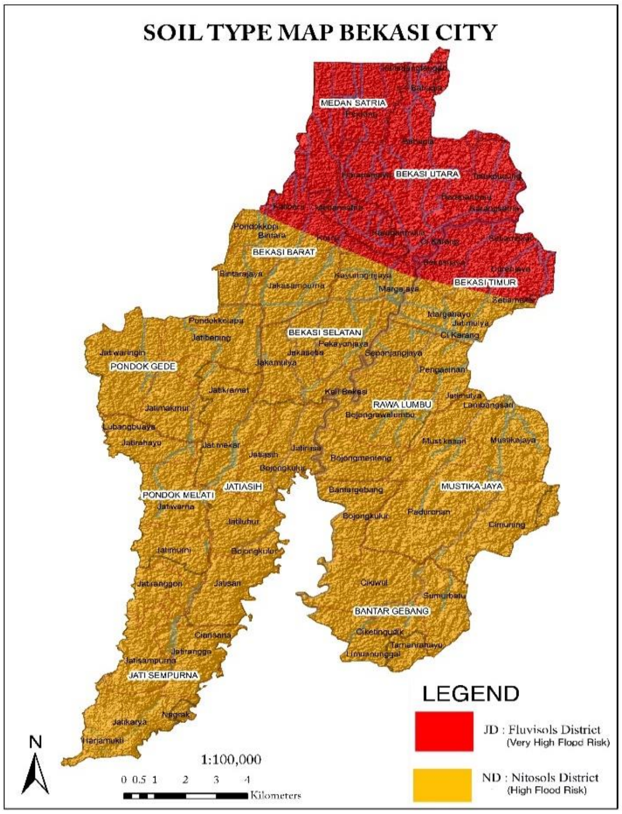

Fig. 8 Soil Type Parameter Map

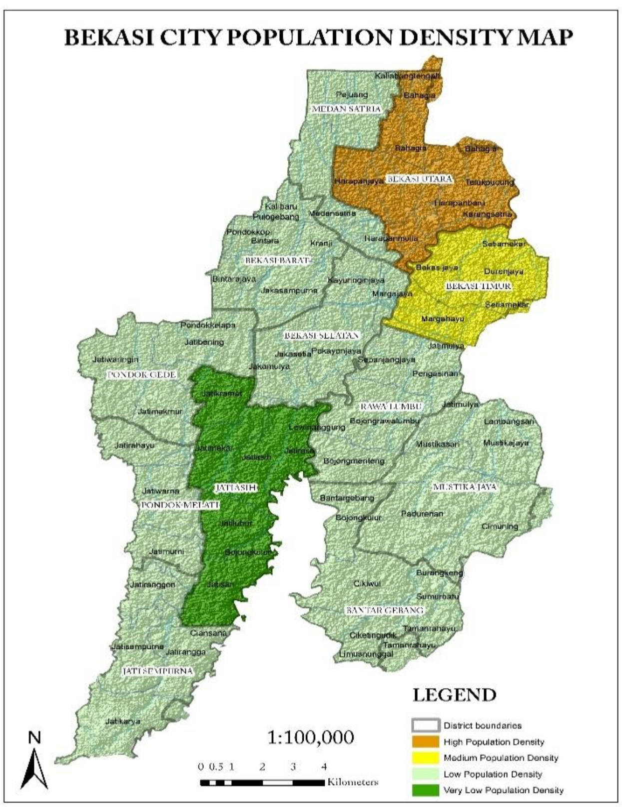

Fig. 9 Population Density Parameter Map

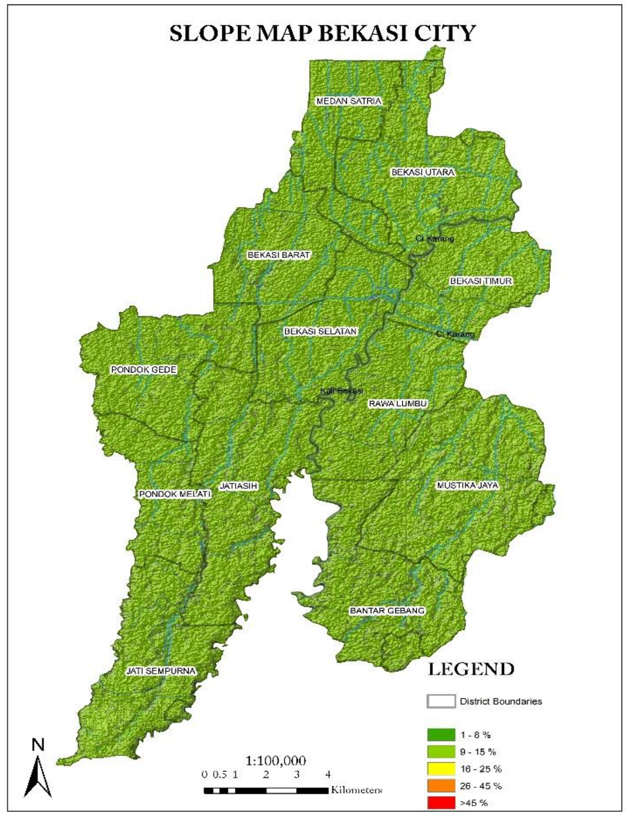

Fig. 10 Slope Parameter Map

The slope of the hill is one of the seven reasons for flooding in Bekasi City (9.345%), which includes one of them. Fig. 10 shows a map of Slope Factors. With a slope of >45%, 3.68 percent of the territory in Bekasi City produces severe floods, as depicted in red on the map. Bekasi City is prone to severe floods at 9.55%, as seen in orange on the map, with a slope of 25-45%. 10.05%, which generates moderate flooding in Bekasi City, shown in yellow, with a slope of 15-25% on the map. 9.68%, which generates modest flooding in Bekasi City, as shown by the light green colour and 8-15% slope on the map and 67.02%, which generates extremely mild flooding in Bekasi City, as shown by a dark green colour with a gradient of 0 to 8% on the map.

4.3. Mapping from Overlaying All GIS Parameters

After the results of the digital map data per parameter have been determined, all these parameters are integrated using ArcGIS software to overlap or superimpose maps. Fig. 11 shows a map of the data for flood risk in Bekasi City based on the overlay of all GIS data. The results show that the area with a very low level of flood vulnerability covers 4.7722 km2 or 2.231361756% of the area, shown in dark green on the map. Areas with a low level of flood vulnerability cover 46.0392 km2 or 21.52678223% of the area, shown by the light green colour on the map. The area with a moderate level of vulnerability to flooding covers 85.4519 km2 or 39.95517825% of the area, shown in yellow on the map. Areas with a high level of flood risk covering an area of 70.4756 km2 or 32.95263371 percent of the total area, are shown in orange on the map, and areas with a very high level of flood vulnerability are 7.1305 km2 or 3.334044047% of the total area, shown in red on the map.

4.4. Aggregating AHP and GIS Parameters

After the ArcGIS overlay map has been determined, the AHP findings are added to the ArcGIS program using the field calculator's menu. It is possible to do weighing, get results, and see graphics that reflect them. This is determined by multiplying the AHP's weight by the findings of the area's real circumstances.

Fig. 12 shows a map of the flood hazard results in Bekasi City based on the combination of AHP and GIS methods. The map shows that the area with a very low level of flood vulnerability is 1.863267 km2 or 0.871026378% of the area, indicated by the dark green color on the map. The area with low flood vulnerability covers 47.77229 km2 or 22.33223942% of the total area, shown in light green on the map. Areas with a moderate level of vulnerability to flooding cover 98.20592 km2 or 45.90858252%, shown in yellow on the map. Areas with a high level of flood vulnerability are 58.36734 km2 or 27.28513561 percent of the total area, shown in orange on the map. Areas with a very high level of flood vulnerability are 7.707437 km2 or 3.603016066% of the total area, shown in red on the map. This shows that 76.7967342 percent of the city area is threatened by moderate to very high flooding.

4.5. Validation

Validation is performed by linking data from INARisk BNPB to the Bekasi City Flood DEM map. Then, comparisons were made using Arc GIS software. The image shown in Fig. 13 is the BNPB INA Risk validation map. According to the validation test results, numerous existing matches, including East Bekasi, North Bekasi, and South Bekasi, have a high degree of match for flood risk. According to the results of the data validation test, the Jatiasih, Pondok Melati, and Jati Sampurna regions are compatible with low flood-risk zoning.

4.6. Strategies

Long-term flood risk management at the city's DAS indicates a mixed approach to managing flood risk (a mix of structural and non-structural measures). Therefore increasing Bekasi's land area available for development is one recommendation for reducing the severity of flood disasters. Prompt mitigation and preparation steps should be implemented to reduce the potential negative consequences of floods on lives and livelihoods, as outlined below. Land planning, in conjunction with building standards, infrastructure, and design techniques, may significantly lessen the vulnerability of communities and urban activities.

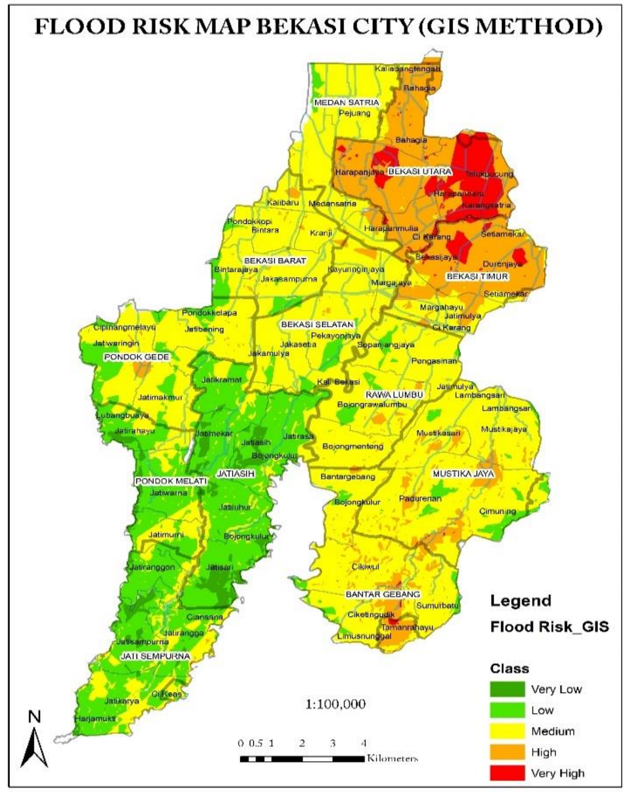

Fig. 11 Risk Map at Bekasi City (real condition using GIS Method).

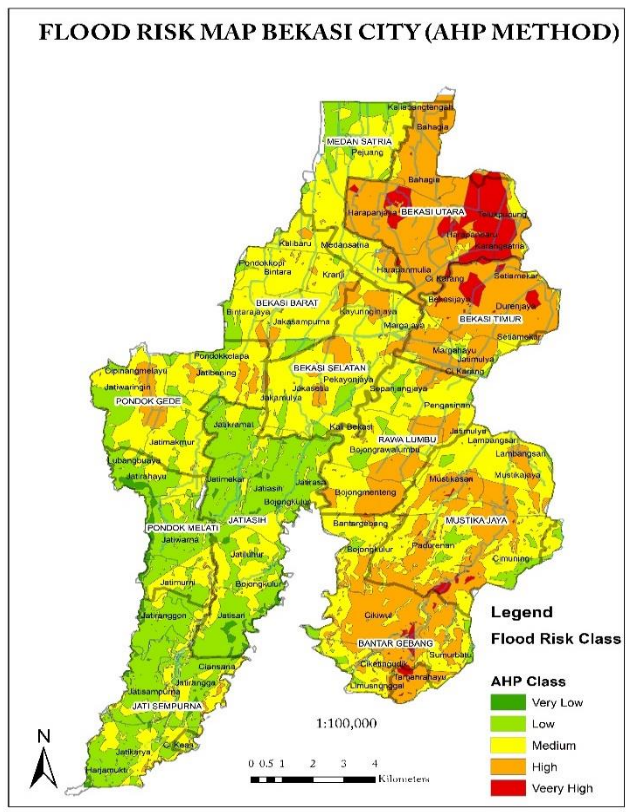

Fig. 12 Risk Map at Bekasi City (using AHP and GIS Method)

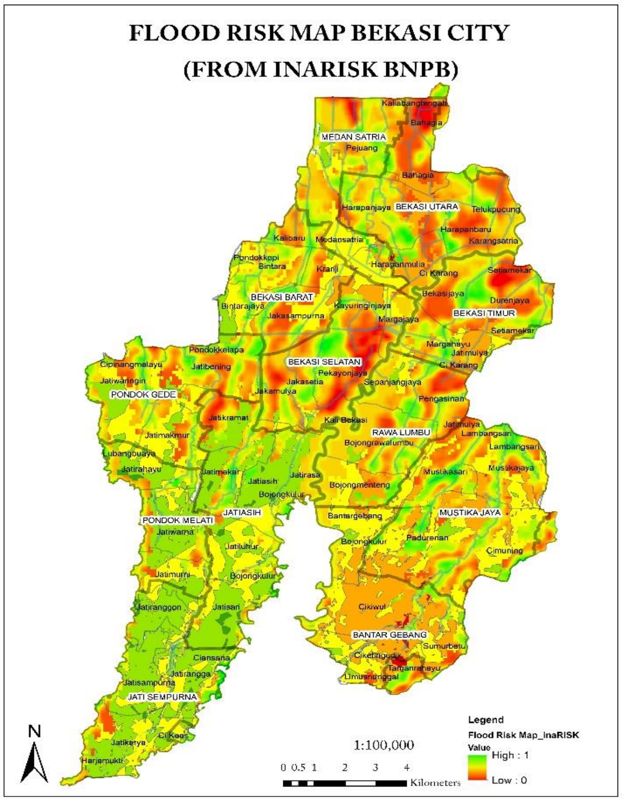

Fig. 13 Risk Map at Bekasi City (using AHP and GIS Method)

The exploitation of water resources Long-term and short-term sustainable planning and integrated flood control must be incorporated. Continuous Drainage System should be implemented in urban areas since it reduces the effect of urban growth on floods and waterway pollution.

Improvement of the hydrological circulation of distributed rainwater (such as the use of water-permeable bricks on plots and road pavements, as well as the construction of sunken green belts, infiltration wells, infiltration tubes, infiltration channels, and infiltration ponds in front of and behind buildings) must be carried out in order to construct urban rainfall storage and absorption space that is suitable for the local environment. Expand, enlarge, and enlarge the airways, and the government may dredge trash and silt that clogs rivers and canals, as the density of rivers inhibits air passage into the earth, reducing the risk of floods. Construct an urban rainwater storage catchment system, and release more city parks and green spaces that can absorb rainfall as it rains. Construct reservoirs to prevent flooding downstream and mitigate the severity of the danger of flood disasters. Construct flood-generating regions and flood storage areas to alter the geographical distribution of floods and lessen the risk of flooding in high-population, high-asset-density locations. Construct structures to aid in flood evacuation. Construct evacuation channels and interim evacuation facilities.

Establish flood alert and emergency response plans. Attention must be paid to the cooperation between urban development and flood problems via adequate spatial planning, land use planning and management. Sustainable flood risk management requires the compilation of flood hazard and risk maps and the partitioning of the land into no-build zones, no-build zones, and no-build zones. Environmental education should be stressed to cultivate civic duty among individuals. A watershed-integrated strategy to flood control should be implemented since it is crucial to address several water-related issues at the watershed level.

5. Conclusion

This study examines flood risk and hazard in Bekasi City, Indonesia, using an analytical hierarchy process (AHP) and a geographic information system (GIS), and offers mitigation methods for the long-term effects. According to the findings of the AHP dam pareto analysis, it can be concluded that the land use/cover, drainage speed, rainfall intensity, elevation, and soil type all have a major impact on projecting flood risk in Bekasi City. The initial iteration of the problem questioned what variables influenced the flood tragedy the most. The elements that are given the most weight are the Land Use and Land Cover factors, whereas the Slope Slope components are given the least weight.

The shape of the flood risk map utilizing the AHP and GIS technologies was questioned in the second issue formulation. ArcGIS and BPMSG software was used to calculate and analyze the overall outcomes of the GIS and AHP methodologies. The findings indicate that 1.863267 km2, or 0.871026378% of the total area of Bekasi City, has a very low degree of flood risk. Low-risk flood zones occupy 47.77229 km2, or 22.33223942%, of the land surface. There are 98,20592 km2 (or 45.90858252%) of land with significant flood risk. There are 58.3673 square kilometres (or 27.28513561 percent) of flood-vulnerable areas. There are 7.707437 km2 (3.603016066%) of very flood-vulnerable areas. According to the estimations provided in the findings chapter, moderate to very high flooding poses a hazard to 76.8% of the Bekasi city area. Additionally, it is clear from the risk map that there is a very significant flood danger in the North Bekasi and East Bekasi regions.

The third problem formulation posed a question concerning potential solutions. In order to make the region in Bekasi City completely secure from a flood-prone scenario, it is possible to apply a plan that involves increasing the land-use efficiency of the city by up to 98.42 km2. This is made feasible by moving or shifting population centers, creating additional city parks, and creating green spaces that can catch rainwater when it rains. Because rivers' density also prevents water from penetrating the earth, the government must expand their length and width to 2101.3 m, and they can dredge garbage and debris that clogs rivers and canals.

6. Author's Note

The author certifies that publishing this paper does not involve any conflicts of interest. The authors affirm that their article is original.

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