Flood Prone Area Analysis using Landsat 9 and MCDA Method in Bekasi Regency

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Abstract. Mapping reveals Bekasi (total 126,266.77 ha) has four flood vulnerability classes. Most land (68.5% or 86,454.87 ha) is Medium risk, primarily in transitional zones prone to inundation from extreme rain or land-use changes. High-risk areas cover 21,831.52 ha, while Low-risk zones span 17,980.39 ha. This distribution shows the regency is predominantly moderate-to-highly vulnerable, driven by lowland topography and proximity to rivers. As West Java's most flood-damaged region in the past decade, a study integrated Landsat 9 imagery and MCDA to map flood risk using five parameters (land cover, elevation, rainfall, soil, river buffers). Validated with BNPB historical data, the model confirmed northern areas (Tambun, Muara Gembong, Babelan) as highest risk due to low elevation (<10 m), alluvial soil, and frequent flooding.

Keywords: Bekasi Regency; Flood; Landsat 9; Multi-Criteria Decision Analysis

I. INTRODUCTION

Flooding is a disaster that frequently plagues communities during the annual rainy season. According to [1], flooding occurs when water cannot be contained in drainage channels or its flow is obstructed, causing it to overflow and inundate surrounding areas. The greatest impact comes from drainage flooding during rainy seasons, which temporarily disrupts economic activity [2].

Bekasi Regency ranks among Indonesia's most flood-prone zones. Reference [3] identifies it as West Java's highest flood-loss area over the past decade. Per Indonesia's National Disaster Risk Assessment (KRB), flooded areas in Bekasi covered 125,172.77 hectares by 2022. The 2021 extreme event damaged >36,000 homes, claimed 8 lives, and injured >200 people, demonstrating severe infrastructure damage and human casualties.

A Geographic Information System (GIS) is a system for collecting, storing, analyzing, and presenting data related to geographic locations, integrating spatial and attribute data for in-depth analysis of geographic phenomena. GIS components include high-capacity hardware, modular, data-driven software, geographic data and information, and management [4]. In flood mitigation, remote sensing satellite imagery plays a crucial role for real-time monitoring, mapping vulnerable areas, and analyzing land and topographic changes. Flood analysis in Bekasi is crucial given the high rainfall and poor drainage. Landsat 9 imagery can be leveraged for greater accuracy because it provides high-quality, continuous data, including improved radiometric precision (OLI-2) and thermal accuracy (TIRS-2), with free global revisions every 8 days [5].

For flood vulnerability analysis, Multi-Criteria Decision Analysis (MCDA) comprehensively integrates parameters such as rainfall, elevation, and land use within a Geographic Information System. The combination of Landsat 9 data and MCDA provides accurate analysis results and supports data-driven decision-making [6]. Conceptually, MCDA is suitable for complex spatial analysis because it is able to integrate various criteria through weighting, producing flood vulnerability maps [7]. The five main parameters used include: land cover, land elevation (DEMNAS/BIG), rainfall (CHIRPS), soil type (FAO/UNESCO), and river (riparian) zones (DAS/KLHK). The integration of these parameters allows for scientific weighting for accurate flood vulnerability mapping.

II. METHODOLOGY

2.1 Research Location

The focus of this research location is Bekasi Regency located at coordinates 6º 10’ 53” - 6º 30’ 6” South Latitude and 106º 48’ 28” - 107º 27’ 29” East Longitude [11]. Bekasi Regency is located in West Java Province and is flanked by DKI Jakarta Province to the west, Karawang

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Regency to the east, the Java Sea to the north, and Bogor Regency to the south (Fig. 1).

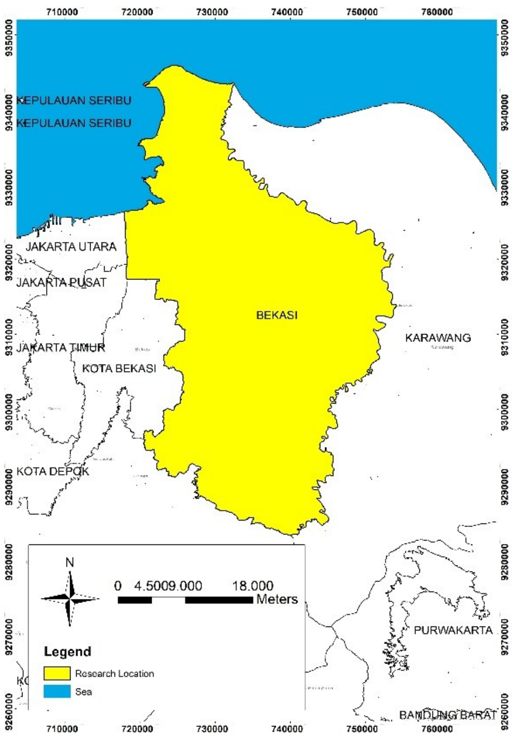

Figure 1. Research Location

2.2 *Tools and Materials*

The data, software, and hardware used for this final project are as follows:

a) Laptop as the primary device for running data processing software, performing spatial analysis computations, map visualization, and storing research data.
b) Handheld GPS as a tool for determining sample coordinates for land cover analysis.
c) Google Earth Engine for processing satellite imagery and land cover classification.
d) Software for processing and displaying spatial data.
e) Microsoft Office software licensed by ITS was used to create the research report.

The materials used for this research are as follows:

a) Landsat 9 Satellite Imagery (Path 122 Row 64, Year 2024, Type L2T). The primary data source for land cover parameter analysis earthexplorer.usgs.gov.
b) CHIRPS rainfall data for 2024 (Climate Hazards Center InfraRed Precipitation with Station data) for analyzing rainfall patterns and intensity as a trigger for flooding.
c) DEMNAS (National Digital Elevation Model) data for Bekasi Regency to calculate land elevation. The data source is the Geospatial Information Agency (BIG) website via Ina-Geoportal.
d) River basin area/watershed data to determine water catchment areas and river flow patterns that influence flood risk. The data source is the Ministry of Environment and Forestry (KLHK).
e) Soil type for analyzing soil permeability and water absorption capacity to predict surface runoff. The data source is the FAO (Food and Agriculture Organization) of UNESCO.

2.3 *Data Processing*

This research method includes six key stages of data processing for the analysis of flood-prone areas in Bekasi Regency. Each stage focuses on the extraction and integration of flood vulnerability parameters through a spatial and multi-criteria approach.

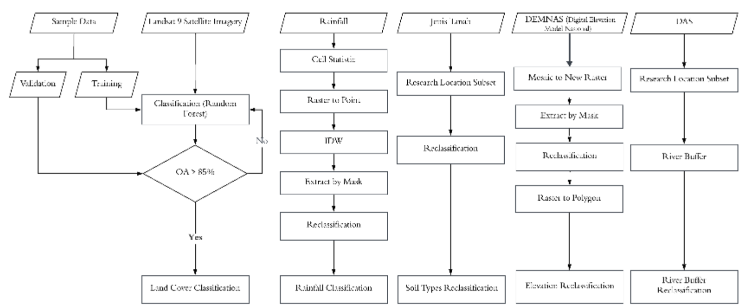

Figure 2. Research Flow Chart

The following is a detailed explanation of each processing stage as described in Fig. 2:

a) Landsat 9 Satellite Imagery Data
Landsat 9 satellite imagery data processing was performed using the Google Earth Engine (GEE) platform. The classification method used was Random Forest with 200 decision trees. The sample points used consisted of 25 points for training data (5 points per class) and 40 points for validation data (8points per class).

b) Rainfall
CHIRPS rainfall intensity and distribution data are used to identify rainfall patterns and classify their

potential contribution to flood risk. Rainfall data is first adjusted to the study area boundaries through a process of cutting the research area of the study location. The data is then calculated using the Raster Calculator and converted to point format using Raster to Point. These rainfall points are processed using the IDW (Inverse Distance Weighting) interpolation method to produce a continuous rainfall distribution map.

c) Soil Type
Information on soil characteristics, such as texture and permeability, plays a role in determining water absorption and flood potential. Data from the FAO will help determine the dominant soil type in an area within the Area of Interest (AOI).

d) Elevation
DEMNAS data is used to determine land elevation within the study area. This data is first segmented based on the study site boundaries. The resulting elevations are classified into several elevation classes to facilitate analysis of the region's topography.

e) Watershed
The area, which forms a single hydrological unit, is used to understand water flow patterns and their impact on flood risk in a specific area. The obtained watershed data is processed using the Multi Ring Buffer function.

f) Scoring
The process begins by assigning a score to each parameter influencing flood vulnerability following Table 1.

TABLE 1. PARAMETER SCORING

Parameters	Class	Description	Score
Land Cover	Forest		1
	Bushes		2
	Plantation		3
	Rice Field/Pond		4
	Residential Area		5
Rainfall	<1500	Very Dry	1
	1501 - 2000	Dry	2
	2001 - 2500	Humid	3
	2501 - 3000	Wet	4
	>3000	Very Wet	5
Soil Type	Alluvial, Planosol, Grey Hydromorphic, Groundwater Lateric	Not Sensitive	5
	Latosol	Slightly Sensitive	4
	Brown Forest Soil, Mediterranean Soil	Medium Sensitive	3
	Andosol, Laterik, Grumosol, Podsol, Podsolic	Sensitive	2
	Regosol, Litosol, Organosol, Renzina	Very Sensitive	1
Elevation	<10 m		5
	10 - 50 m		4
	50 - 100 m		3
	100 - 200 m		2
	>200 m		1
River/Watershed	0 - 25 m	Highly Vulnerable	5
	25 - 100 m	Prone	3
	100 - 250 m	A Bit Prone	1

(Source: Theml, S. 2008: Katalog Methodologi Penyusunan Peta Geo Hazard dengan GIS; Primayuda, 2006; Darmawan dan Prayogi)

g) Scoring and Weighted
Next, an overlay is performed between parameters to combine the spatial information comprehensively. Afterward, weighting factor in Table 2 is applied to determine the level of influence of each parameter on flood potential.

TABLE 2. SCORING AND WEIGHTED

Parameter	Weight
Rainfall	0.2
Land Cover	0.2
Elevation	0.1
Soil Type	0.2
River Buffer	0.3

(Source: Pandulu, 2016)

$$Interval\ (i) = \frac{R}{n} \tag{1}$$

R is the Difference between the maximum and minimum scores and n is the number of flood-prone area classes. Furthermore, historical data on flood-prone areas from the National Disaster Management Agency (BNPB) is used as a reference in the analysis phase to increase the accuracy of the results.

III. RESULT AND DISCUSSION

3.1 Land Cover Map

Land cover map in Fig. 3 has overall accuracy of 88.57% and the kappa value of 85.64%. The classification process began with image preprocessing, which included optical and thermal band-scale correction and the calculation of four vegetation and water indices (NDVI, NDWI, MNDWI, NDBI). Calculation of the area shows the distribution of land cover as follows: Forests covering an area of 9,315.746247 hectares, Bushes covering an area of 33,094.15389 hectares, Fields/Gardens covering an area of 29,667.31092 hectares, Rice Fields/Fish Ponds covering an area of 23,797.23006 hectares, and Settlements as the largest class with 30,932.33142 hectares.

3.2 Rainfall Map

This map reveals rainfall intensity patterns as the primary trigger for flooding, with vulnerability scores increasing with precipitation intensity. On the map (Fig. 4), the northern region of Bekasi Regency is dominated by the dry category (light blue), while the central region falls into the humid to wet category (light blue to medium blue). Rainfall scores also increase from north to south, with the highest score (5) in areas classified as very wet.

3.3 Elevation Map

Based on elevation classification, the northern to central areas of Bekasi Regency are dominated by zones with elevations of less than 10 meters above sea level, indicated by dark red.

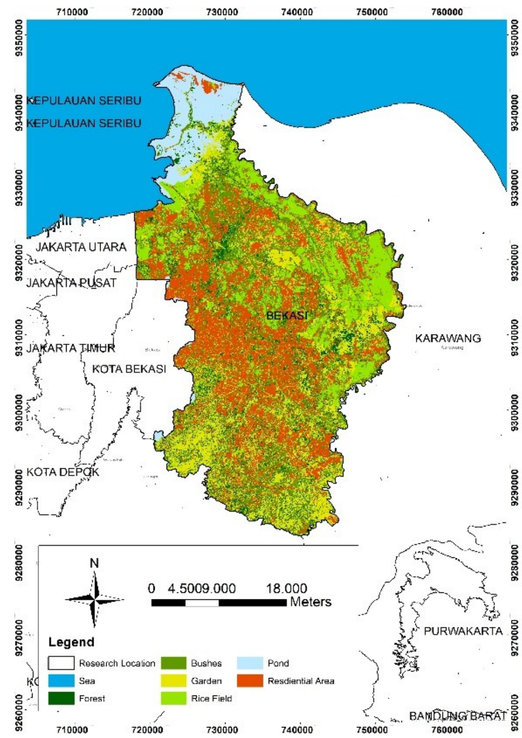

Figure 3. Land Cover Map

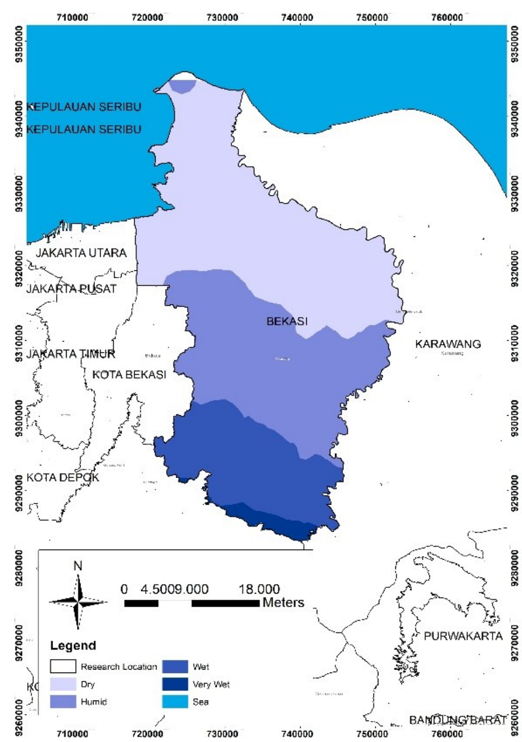

Figure 4. Rainfall Map

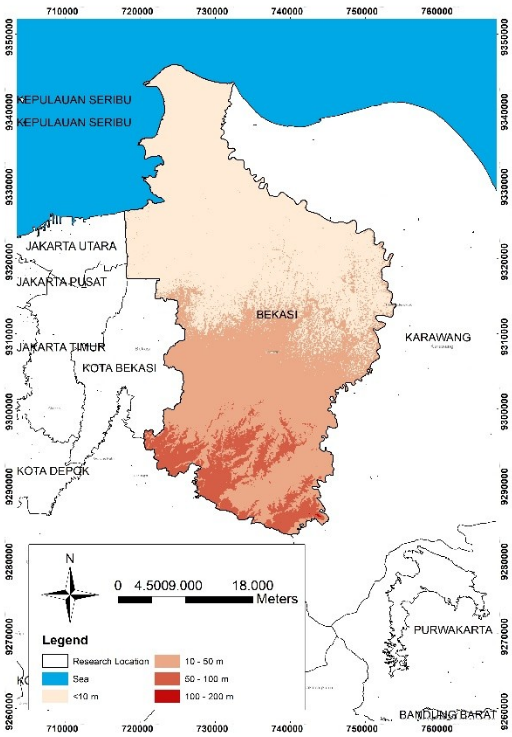

Figure 5. Elevation Map

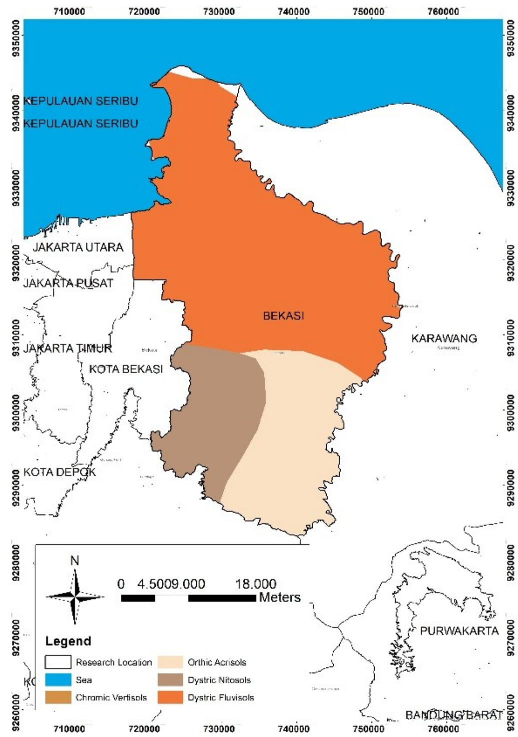

Figure 6. Soil Type Map

Areas with elevations below 10 meters are potentially prone to waterlogging due to their low slopes, while higher elevation areas in the south tend to have greater potential for surface runoff and differing geomorphological conditions (Fig. 5).

3.4 *Soil Type Map*

Dystric Fluvisols, which are equivalent to Alluvial soils in Table 3, dominate an area of 6,514 km². The second largest area is occupied by Dystric Nitosols, covering 2,153 km², whose characteristics are equivalent to Latosol soil (Fig. 6). This soil type is somewhat sensitive (score 4) to infiltration, indicating a fairly good water absorption capacity, although not as optimal as Alluvial soil.

3.5 *River Buffer Zone*

The river buffer zone in Fig. 7 categorizes vulnerability based on proximity to the watercourse. The closer to the riverbank, the higher the risk of overflow, making this parameter a dominant determinant in the MCDA model.

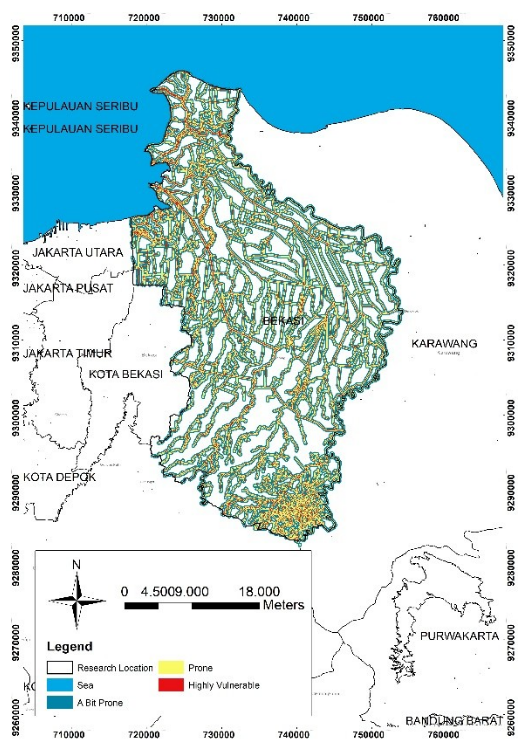

Figure 7. River Buffer Zone

3.6 Flood Prone Area Map

The frequency distribution used indicates that the total value or possible score ranges from a minimum of 0 to a maximum of 4.6.

TABLE 3. FLOOD PRONE AREA INTERVAL

Class	Interval
High	3.06 – 4.6
Medium	1.53 – 3.06
Low/Safe	0 – 1.53

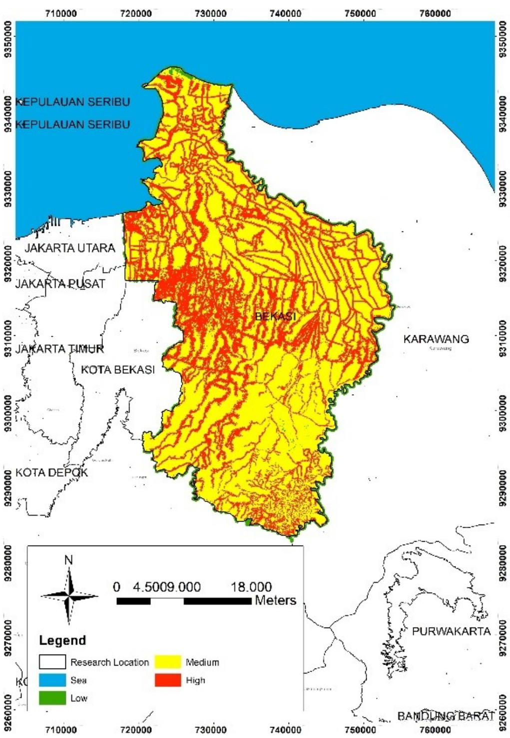

Figure 8. Flood Prone Area Map in Bekasi regency

The "High" category covers scores ranging from 3.06 to a maximum of 4.6., meanwhile the "Medium" category covers scores ranging from 1.53 to less than 3.06 and finally, the "Low" category covers scores from 0 to less than 1.53 (Table 3 and Fig. 8).

CONCLUSION

Based on mapping results, Bekasi Regency is divided into three flood vulnerability classes, covering a total area of 126,266.77 hectares. The Low class encompasses 17,980.39 hectares. The Medium class covers 86,454.877 hectares, approximately 68.5% of the total flood-prone area, primarily in transitional zones susceptible to inundation during extreme rainfall or due to land-use changes. Meanwhile, the High class spans 21,831.52 hectares. This distribution indicates that most of Bekasi Regency falls into the moderate to highly vulnerable flood categories, with dominant contributing factors being lowland topography and proximity to hydrological networks.

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