



Flood Hazard Mapping in Bone Regency Based on Geographic Information System (GIS)

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Abstract

Bone Regency is one of the regions in South Sulawesi Province with a high-category flood disaster risk level, reaching a risk index of 164.46. This study aims to produce flood hazard mapping in Bone Regency using a Geographic Information System (GIS) approach and fuzzy logic. The methods employed include Geomorphic Flood Index (GFI) analysis to identify areas prone to inundation, as well as weighted overlay techniques based on slope and distance-from-river parameters. The research results indicate that the total area with flood hazard levels in Bone Regency reaches 93,773.14 ha, dominated by the high-hazard class covering approximately 75% of the total hazard potential. The spatial distribution shows the highest risk concentration in Mare Subdistrict (10,920.15 ha), Sibulue (9,062.06 ha), and Cenrana (6,968.28 ha). Model validation against historical data demonstrates an accuracy rate of 90%, proving that the integration of GIS and fuzzy logic is effective in mapping flood hazard zones with high precision. The results of this study are expected to serve as a strategic instrument for stakeholders in planning more effective and targeted disaster mitigation.

Keyword: Flood, GIS, Fuzzy Logic, Bone Regency, Hazard Mapping.

INTRODUCTION

Natural disasters in general can be classified into two categories: actual disasters and potential disasters. Floods fall into the category of actual disasters because they often occur





suddenly, progress rapidly, and result in a relatively high number of casualties and physical damage (Angriani & Kumalawati, 2016). This phenomenon occurs due to excessive water accumulation during the rainy season and the overflow of river flows that exceed their natural carrying capacity. In Indonesia, floods are natural events that are difficult to predict accurately due to their dependence on weather cycles, except in areas that have become habitual disaster locations (Seprianto et al., 2024).

Bone Regency, as one of the largest districts in South Sulawesi, faces serious challenges related to the complexity of flood threats. Geographically, the vulnerability of this region is influenced by factors such as slope, land elevation, soil type, and high river density, particularly within the Walanae River Basin (DAS) system (Seprianto et al., 2024). These physical conditions, when combined with above-normal rainfall, cause the drainage and water retention systems to be unable to accommodate the accumulated water discharge, leading to overflow into residential areas. The disaster risk index reaching 164.46 indicates that Bone Regency is in the high-risk category, where flood impacts not only damage buildings and infrastructure but also disrupt economic stability and regional development (Angriani & Kumalawati, 2016).

The flood problem in this area is becoming increasingly severe along with rising population density in vulnerable zones. Floods cause massive property losses, ranging from damage to homes to vital public facilities (Rosyidie in Angriani & Kumalawati, 2016). In addition to natural factors, failures in water diversion systems are often worsened by human behavior and river shallowing due to sedimentation (Seprianto et al., 2024). Given that flood disasters cannot be completely prevented, a better disaster management system is required through the utilization of spatial-based technology.

Previous studies have identified that several areas, such as Dua Boccoe Subdistrict, have been flood-prone locations for more than 20 years (Musfida et al., 2021). The high intensity of flooding in the area is caused by three main factors: extreme daily rainfall, water inflows from upstream areas in Soppeng and Wajo Regencies, and permanent sedimentation in the Walanae River Basin (Musfida et al., 2021). The peak of the rainy season, occurring in May and June with monthly rainfall reaching 589 mm, often causes river discharge to increase dramatically beyond the capacity of existing structural mitigation measures (BPBD Bone Regency, 2024).

The use of Geographic Information Systems (GIS) has become a crucial solution for identifying flood vulnerability levels quickly, easily, and accurately. GIS technology enables weighted overlay analysis of various flood-determining parameters such as rainfall, land use, and soil texture (Seprianto et al., 2024). Through flood hazard mapping, communities can increase awareness of risks in their environment, enabling more targeted preparation and preventive



actions (Liu et al. in Seprianto et al., 2024). In addition, presenting data in digital

Imap form greatly assists the government in planning more effective and efficient disaster management strategies in the future.

This study aims to produce flood hazard mapping in Bone Regency using a GIS approach. With precise identification of hazard zones, the results of this study are expected to serve as a decision-making instrument for relevant authorities and as educational material on disaster risk for the community. The integration of spatial data is a strategic step toward building regional resilience in facing the uncertainty of hydrometeorological phenomena in Bone Regency.

METHOD

Hazard assessment aims to determine the extent of the affected area and the hazard index that reflects the probability and intensity of the event. The probability aspect is analyzed through the historical frequency of disasters, while intensity describes the magnitude of physical impacts. The high-to-low categories are presented in the form of an index value ranging from 0 to 1, with the following classifications:

1. Low hazard class (0 – 0.333);
2. Moderate hazard class (0.334 – 0.666);
3. High hazard class (0.667 – 1).

The preparation of the hazard map refers to the methodology of the National Disaster Management Agency (BNPB) and the Technical Module for Flood Disaster Risk Mapping 2019. The analysis process was carried out using Geographic Information System (GIS) software through weighted overlay techniques on the hazard-composing parameters. The main data sources used include the National DEM (8.33 meters) for geomorphological analysis and river network data from BIG. Details of the parameters and data sources used in the calculation can be seen in Table 1.

Table 1. Flood Hazard Parameters

Paramater	Data Used	Data Source	Year
Flood-Prone Are	National DEM 8.33 meters	BIG	2018
Slope	Elevation Data (DEM)	BIG	2018
Distance from River	River Network	BIG	2017

Source: Disaster Risk Assessment of Bone Regency 2020–2024, BPBD Bone Regency.

Areas with potential inundation were detected using the Geomorphic Flood Index (GFI) method, which focuses on the geomorphological conditions of the region, such as flow accumulation due to high rainfall or river overflow. Determination of the River Basin (DAS) was based on DEM data to identify water accumulation areas. Based on the GFI threshold of -0.53 (Samela et al.), each point was classified as a flood-prone zone ($GFI > -0.53$) or non-prone ($GFI < -0.53$). As shown in Figure 3, the GFI value is obtained by comparing each point in the river basin between water depth (h_r) and the elevation difference (H) between the tested point (green) and the nearest point to the river network (red). Water depth (h_r) is calculated as a function of the area contribution value (A_r) within the nearest hydrologically connected area to the tested point (Samela et al., 2015), as illustrated in Figure 1.

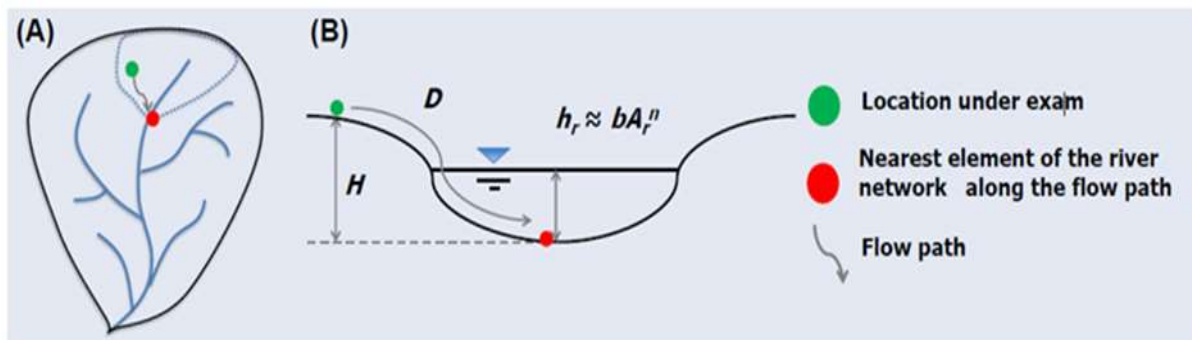


Figure 1. Cross-Section Description of GFI Methodology. Samela et al., 2015

Source: Technical Module for Flood Disaster Risk Mapping 2019.

The hazard index in prone zones was determined using a fuzzy logic approach to obtain a degree of truth within the range of 0–1. The two main parameters used were:

1. Slope: Using a midpoint value of 5% (moderately gentle). The smaller the slope value, the higher the hazard index.
2. Horizontal Distance from River: Using a midpoint value of 100 meters. The hazard index increases as the distance from the river network decreases.

The determination of flood hazard levels in this study was carried out through the formulation of a rule base matrix that integrates slope and horizontal distance-from-river parameters. “If-Then” logic was applied to determine the weight index for each parameter combination, where the value represents the degree of hazard potential at a location. These rules were developed to ensure that areas with the most vulnerable geomorphological characteristics—such as very gentle slopes and very close proximity to rivers—receive the highest hazard index scores. In detail, the fuzzy logic combinations used to generate the flood hazard index are presented in

Table 2 below:

Table 2. Fuzzy Logic Rule Matrix for Flood Hazard Index

Slop	Distance from River	Flood Hazard Index
Gentle (< 5%)	Close (< 100 m)	High
Gentle (< 5%)	Moderate (~ 100 m)	High
Gentle (< 5%)	Far (> 100 m)	Moderate
Moderately Gentle (~ 5%)	Close (< 100 m)	High
Moderately Gentle (~ 5%)	Moderate (~ 100 m)	Moderate
Moderately Gentle (~ 5%)	Far (> 100 m)	Low
Steep (> 5%)	Close (< 100 m)	Moderate
Steep (> 5%)	Moderate (~ 100 m)	Low
Steep (> 5%)	Far (> 100 m)	Low

Source: Disaster Risk Assessment of Bone Regency 2020–2024, BPBD Bone Regency.

The final result was obtained through the fuzzy overlay function to combine the two parameters into a representative flood hazard index.

RESULTS AND DISCUSSION

Results of Flood Hazard Mapping in Bone Regency

Based on spatial analysis using weighted overlay methods on slope, elevation, and river network parameters, Bone Regency has a total flood hazard area of 93,773.14 hectares. The modeling results show dominance of the high-hazard class, covering approximately 75% of the total hazard potential across the entire administrative area of the regency. The spatial distribution of flood hazards shows a pattern concentrated in two main zones: the river corridor in the northwest and the low-lying coastal plains in the east. Table 2 details the five subdistricts with the most significant high-hazard areas.

Table 2. Flood Hazard Area by Subdistrict in Bone Regency

No.	Subdistrict	Low	Moderate	High	Total Area (ha)	Class
1	Mare	978.84	1,457.05	8,484.27	10,920.15	High
2	Sibulue	726.10	926.74	7,409.22	9,062.06	High
3	Cenrana	104.33	335.72	6,528.23	6,968.28	High
4	Dua Boccoe	246.13	814.37	5,083.29	6,143.79	High

5	Ajangale	469.08	1,103.79	4,388.40	5,961.27	High
6	Libureng	151.84	1,630.41	3,272.34	5,054.59	High
7	Kajuara	39.84	204.36	4,790.86	5,035.06	High
8	Awangpone	291.89	643.86	3,012.79	3,948.54	High
9	Tonra	199.82	842.42	2,828.01	3,870.25	High
10	Tellu Siattinge	170.29	648.16	2,705.13	3,523.58	High
11	Barebbo	581.90	940.23	1,982.05	3,504.18	High
12	Bengo	95.76	750.10	2,399.12	3,244.98	High
13	Lamuru	32.71	537.01	2,508.34	3,078.06	High
14	Cina	649.03	831.36	1,566.01	3,046.40	High
15	Lappariaja	39.19	481.92	2,142.52	2,663.64	High
16	Bontocani	74.33	977.07	1,499.25	2,550.66	High
17	Palakka	305.78	705.21	1,484.71	2,495.70	High
18	Kahu	100.16	586.64	1,691.08	2,377.88	High
19	Salomekko	58.33	274.56	1,831.04	2,163.93	High
20	Ponre	41.88	700.42	934.66	1,676.96	High
21	Tanete Riattang Timur	158.72	219.57	1,104.01	1,482.30	High
22	Tellu Limpoe	42.03	529.01	646.80	1,217.85	High
23	Ulaweng	41.82	678.42	281.92	1,002.15	High
24	Amali	42.60	289.84	492.47	824.91	High
25	Tanete Riattang Barat	92.39	149.21	418.00	659.60	High
26	Patimpeng	97.45	352.59	202.43	652.47	High
27	Tanete Riattang	109.61	152.79	381.51	643.91	High
Total		5,941.86	17,762.83	70,068.45	93,773.14	High

Source: Flood Contingency Plan of Bone Regency 2024–2027, BPBD Bone Regency

Model validation is a crucial step to ensure that the produced hazard map has a high level of confidence for stakeholders. Validation was performed by spatially comparing high-hazard zones on the digital map with historical flood occurrence coordinate points obtained from field surveys and verification by relevant agencies. Based on testing against 10 representative sample points spread across affected areas, the GFI- and fuzzy-logic-based mapping model accurately identified flood locations at 9 points, resulting in an accuracy rate of 90%. This high level of

agreement is clearly evident in critical areas such as the lowlands around the Walanae River Basin, where high-hazard predictions align with real field conditions that frequently experience inundation up to 2 meters deep. With this significant validation achievement, the mapping instrument has proven effective in capturing the complexity of flood-triggering factors in Bone Regency and is suitable for use as a basis for decision-making in disaster mitigation.

Spatial analysis shows that Bone Regency has significant flood vulnerability, with a total affected area of 93,773.14 ha. All subdistricts in the region are identified as high-hazard categories, with approximately 75% of the total hazard potential in that class. Geographically, the highest hazard concentration is in the eastern and northern zones of the regency, dominated by low-lying topography, coastal areas, and proximity to major river networks.

Subdistricts with the most dominant high-hazard areas include Mare, Sibulue, Cenrana, Ajangale, and Dua Boccoe. On the other hand, western areas such as Bengo and Lamuru Subdistricts also have large risk potential due to being traversed by the Salo Walanae River. The high hazard index is linearly influenced by the presence of large rivers in those areas. For example, in Sibulue Subdistrict, 82% of its area falls into the high-hazard category due to the influence of the Salo Maringki and Salo Pattiro rivers, combined with minimal slope, causing water to overflow laterally over wide areas when discharge increases.

Analysis of Regional Characteristics and Triggering Factors

Flood events in Bone Regency are an annual phenomenon triggered by extreme rainfall accumulation, runoff from upstream areas, and massive sedimentation in the downstream Walanae River Basin. Suboptimal natural resource management in upstream areas worsens sedimentation conditions, drastically reducing river carrying capacity. This causes overflow water to inundate settlements and agricultural land with flood depths reaching adult knee level (about 50 cm), while in riverbank areas, water levels can reach 2 meters.

The duration of inundation in critical areas such as Dua Boccoe and Cenrana is quite persistent, ranging from 1 to 7 days. In contrast, the central city area and southern Bone (such as Mare Subdistrict) tend to experience fast-receding flash floods that subside in less than 24 hours. Although the Bone Regency Government has carried out structural mitigation through the construction of retaining walls and gabions, the complexity of upstream Walanae runoff and economic activities in the northern Bone area often exceed the design capacity of existing flood control infrastructure.

The visualization of mapping results in Figure 2 provides a digital overview of hazard zoning that serves as the basis for technical mitigation planning and community education.

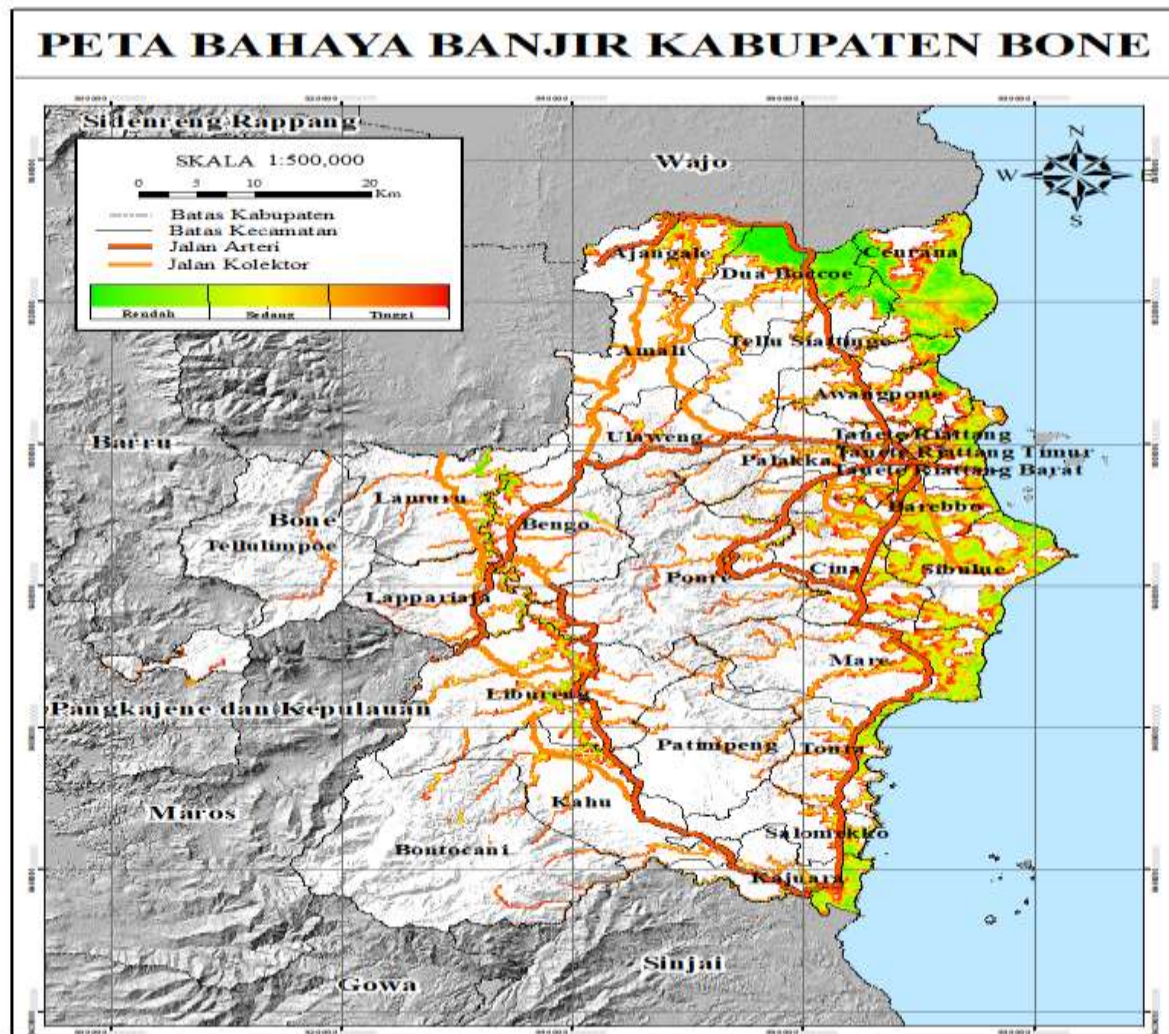


Figure 2. Flood Hazard Map of Bone Regency

Source: Flood Contingency Plan of Bone Regency 2024–2027, BPBD Bone Regency

The mapping results in Figure 4 show that high-hazard zones (red/orange) follow the main river network, particularly the Walanae River Basin (DAS) system. Geographically, flat areas near rivers have a much higher hazard index compared to areas with greater elevation. This is caused by surface runoff that moves slowly in flat areas, thereby increasing the potential for prolonged inundation (Seprianto et al., 2024).



Sibulue and Mare Subdistricts on the eastern coast have unique vulnerability due to the interaction between overflows from the Salo Maringki and Salo Pattiro rivers and sea tides. The minimal elevation difference between the riverbank and settlements causes water to spread laterally quickly when rainfall intensity peaks in May and June (Angriani & Kumalawati, 2016). On the other hand, northern areas such as Dua Boccoe and Ajangale are more influenced by flood inflows from neighboring upstream regencies, exacerbated by river shallowing due to sedimentation.

CONCLUSION

Based on the results of the analysis and discussion, it can be concluded that the integration of Geographic Information Systems (GIS) with a fuzzy logic approach has proven effective in mapping flood hazard zones in Bone Regency with high precision. The modeling results show that the total area included in the flood hazard category reaches 93,773.14 ha, with the dominance of the high-hazard class covering approximately 75% of the total hazard potential.

The spatial distribution shows that the highest risk concentration is in the eastern and northern parts of the regency, particularly in Mare, Sibulue, and Cenrana Subdistricts. The high hazard level in these areas is influenced by low-lying topographic characteristics that interact directly with the Walanae River Basin system, as well as the influence of river overflows and sea tides in coastal areas.

Model validation against historical event data shows an accuracy rate of 90%, confirming that the method used has a high level of reliability. Therefore, the resulting digital flood hazard map is suitable for use by the Bone Regency Government and BPBD as the basis for decision-making, the preparation of technical mitigation strategies, and the development of disaster education materials for the community to minimize future losses.

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