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Original Article

Multi-Parameter Flood Hazard Assessment Using a Spatial Approach in Demak Regency

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ABSTRACT
Flood is a frequent hydrometeorological disaster in Indonesia, and Demak Regency is highly vulnerable due to its coastal and lowland characteristics. This study analyzes flood hazard levels using Geographic Information Systems (GIS) with six parameters: slope, elevation, rainfall, soil type, land use, and river buffer. Weighted overlay was applied to classify hazard zones. Results show that 74% of the area is highly vulnerable, 23% vulnerable, and only 2% not vulnerable. The highest risk occurs in coastal sub-districts such as Wedung, Sayung, Bonang, and Karanganyar, influenced by flat slopes, very low elevation, high rainfall, and land use dominated by rice fields, ponds, and settlements. Meanwhile, southern areas like Karangawen and Mranggen are relatively safer due to higher elevation and undulating topography. It is concluded that flood vulnerability in Demak is driven by multiple physical and environmental factors, requiring integrated mitigation through drainage improvement and land use management.

KEYWORDS
Flood; Hazard; Spatial Approach; Demak Regency

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INTRODUCTION

Disasters are a global threat with significant impacts, characterized by damage to educational facilities, healthcare services, and transportation infrastructure, as well as causing economic losses on a large scale (Benardi et al., 2023). Natural disaster phenomena represent a high-frequency issue in Indonesia and worldwide, with occurrences recorded almost every year. (Benardi et al., 2025; Rahmawati et al., 2024)

Floods are disasters that occur almost every year and have significant impacts on communities in social, economic, and environmental aspects (Kenranto et al., 2024; Tabari et al., 2021). Flood events are generally triggered by the inability of rivers or other water bodies to accommodate excess discharge, especially during periods of high rainfall. These overflow conditions can cause various forms of damage to both the natural environment and built infrastructure (Kenranto et al., 2024) Flooding is one of the most serious and frequently occurring natural disasters in Asia (Dano et al., 2019). Indonesia, due to its geographical position at the convergence of three tectonic plates and its tropical climate that is prone to extreme weather, has a high level of vulnerability to both geological and hydrometeorological disasters (Alfarisi Handifa et al., 2023). Floods are the most dominant hydrometeorological disaster in Indonesia, with most previous studies focusing on densely populated urban areas (Isma et al., 2024; Van Kerkvoorde et al., 2018). The impacts are multidimensional, including loss of life, injuries, material losses, and psychological disturbances among affected communities (Irwan Benardi et al., 2021)

Based on data released by the National Disaster Management Agency (BNPB) in 2024, a total of 2,298 flood events were recorded in Indonesia. These incidents resulted in significant impacts, including 284 fatalities, 42 missing persons, and 11,044 injuries. In addition to human casualties, the disaster caused damage to 40,368 houses and inundated 1,888,983 other houses (BNPB, 2024)

Demak Regency is a northern coastal area consisting of 14 sub-districts with varying land areas. The largest sub-district is Wedung (13%), while the smallest is Kebonagung (4.5%). According to BPS (2025), the population in 2024 reached 1,252,970 people, with the highest concentration in Mranggen Sub-district (14.48%) and the lowest in Kebonagung (3.41%). The sex ratio is recorded at 102, indicating 102 males for every 100 females (BPS, 2025). In 2024, Demak Regency experienced a major flood that had widespread impacts on communities and infrastructure across 11 sub-districts, including Demak, Sayung, and Mranggen. This disaster was triggered by prolonged heavy rainfall, inadequate drainage systems, and river overflow. According to the Demak Regional Disaster Management Agency (BPBD), 93,149 people were affected, with 22,725 of them displaced (BPBD Kab.Demak, 2024). This disaster not only caused material losses but also threatened human safety and public health.(Ahmed, 2024; Aksha et al., 2020)

Verdyansyah's study developed a flood susceptibility model for Demak Regency by integrating remote sensing data, machine learning algorithms (Random Forest, SVM, XGBoost, and multilayer perceptron), and CMIP6 climate projections under various SSP scenarios. The results indicate a significant increase in highly flood-prone areas, particularly under high-emission scenarios (SSP5-8.5).(Verdyansyah et al., 2025). Another study on compound flooding in the coastal area of Demak shows that the combination of long-term factors (sea level rise and land subsidence) and short-term factors (rainfall, river overflow, storms, and tidal influences) expands flood-prone zones by 10–20% compared to considering a single factor alone. (Chrysanti et al., 2024).

Previous studies in Demak have generally focused on physical aspects, such as flood susceptibility using machine learning and compound flooding phenomena. Meanwhile, studies in other regions using multi-criteria spatial analysis are often limited to biophysical factors without integrating socio-economic dimensions and community adaptive capacity. Therefore, this study offers novelty by combining physical, environmental, and socio-economic parameters in a GIS-based spatial analysis to produce a more representative and applicable flood vulnerability map for disaster risk reduction planning in Demak Regency.

The use of Geographic Information Systems (GIS) technology has been widely applied in assessing flood vulnerability, both for mapping flood-prone areas and analyzing contributing factors (Tariq et al., 2021). The objective of this study is to analyze flood vulnerability levels in Demak Regency using a multi-parameter spatial approach based on GIS. The analysis employs six parameters: river buffer, rainfall, soil type, slope, elevation, and land use (Ramayanti et al., 2022a; Tikuye et al., 2025).

Studies on hydrometeorological disasters in Indonesia have been widely conducted; however, they generally focus on densely populated urban areas or adopt a national-scale perspective (Bennett et al., 2023; Manakane et al., 2023). Research specifically analyzing flood vulnerability in Demak Regency using an integrated multi-parameter approach remains limited (Rahman et al., 2022). Therefore, further research is needed by utilizing GIS to integrate various physical and environmental factors (Wulandari et al., 2025). This study is expected to contribute scientifically by developing a spatial-based flood vulnerability map of Demak Regency and supporting more effective disaster mitigation strategies to enhance regional resilience to flooding (Costache et al., 2021; Romadhon & Aziz, 2022)

METHOD

Study Area

This study was conducted in Demak Regency, Central Java, which is geographically located at coordinates 6°43’26”–7°09’43” South Latitude and 110°27’58”–110°48’47” East Longitude. The following figure presents the administrative map of the study area in Demak Regency. (Arga Himawan et al., 2019).

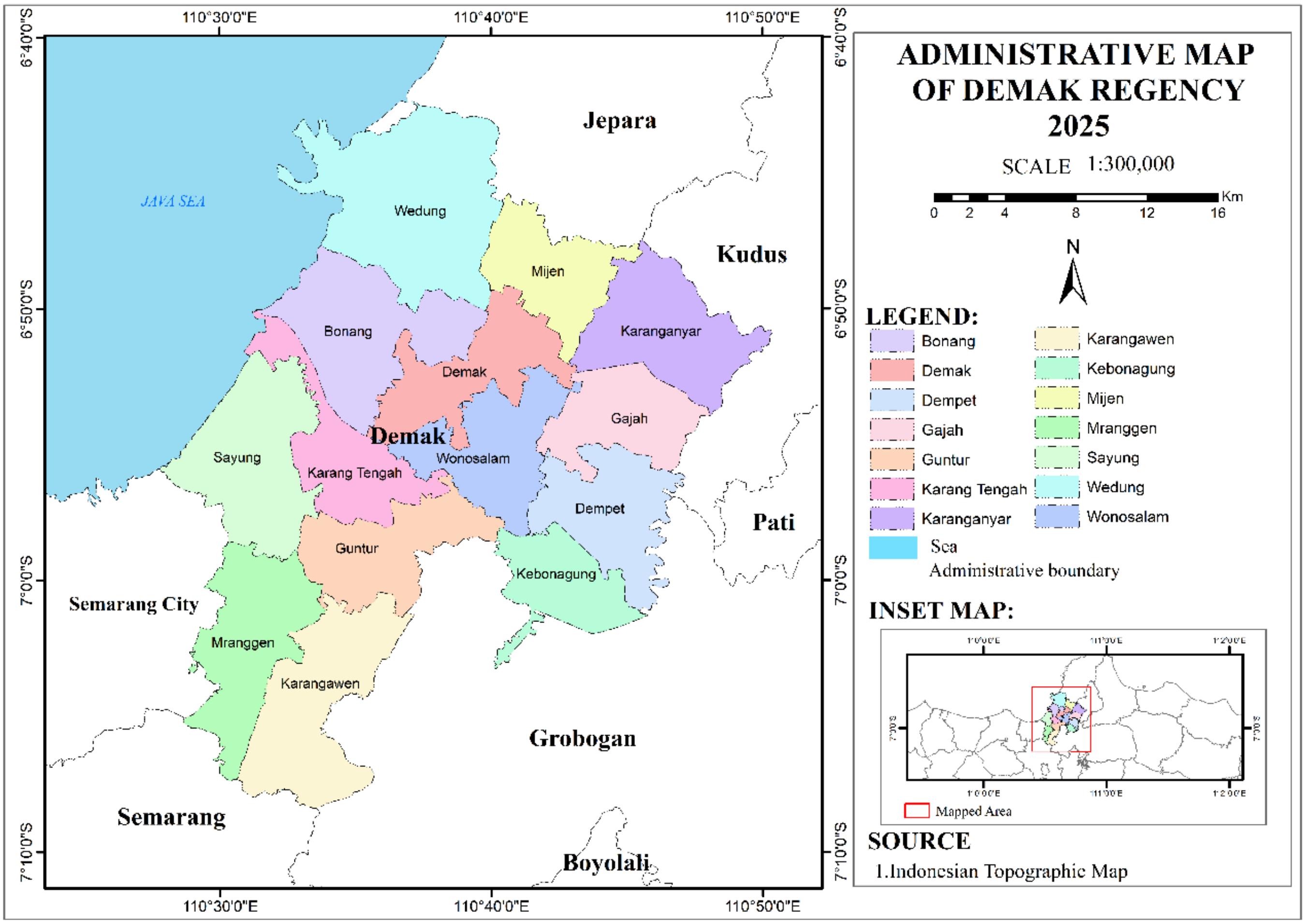

Figure 1. Administrative Map of Demak Regency
Source: Processed Research Data, 2025

Research Approach

This study employs a spatial approach supported by descriptive-quantitative analysis based on Geographic Information Systems (GIS) (Pasongli et al., n.d.). The spatial approach was selected because the focus of the study is to map flood vulnerability levels based on several environmental parameters that have spatial relationships. The data used consist of spatial data (river network maps, soil type maps, land use maps, slope maps, and elevation/DEM data) as well as non-spatial data (rainfall and secondary data from relevant institutions) (Makawimbang et al., 2022)

Research Proceduren

The research procedure can be systematically explained through several stages. To clarify the workflow, a research flowchart is presented, illustrating the steps from data preparation, processing, to result analysis.

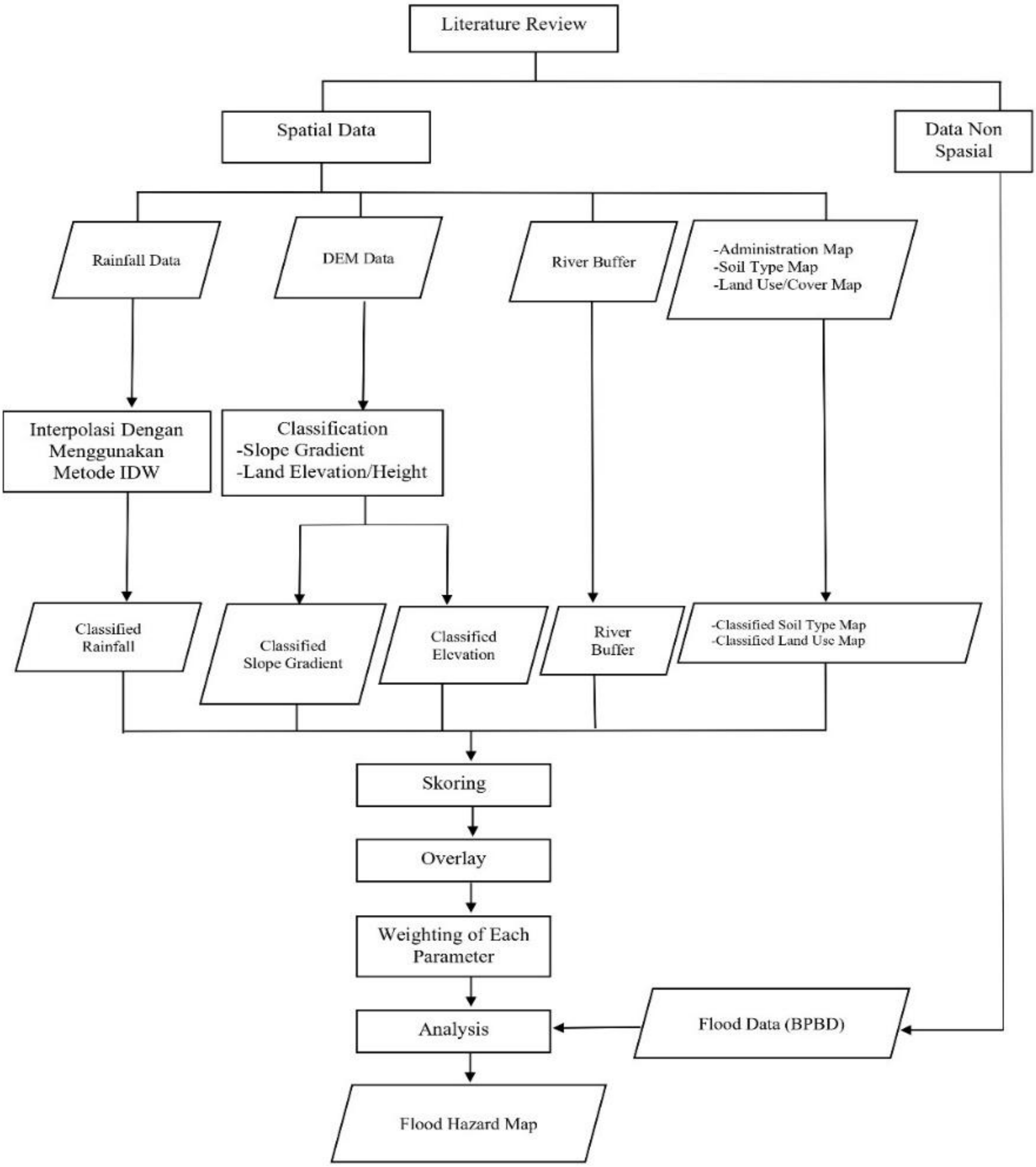

Figure 2. Research Flowchart
Source: Processed Research Data, 2025

Data Collection Instruments

This study utilizes both spatial and non-spatial data obtained from official institutions and scientific literature. The spatial data include river network maps, soil type maps, land use maps, slope maps, and DEM data as the basis for spatial analysis, as well as rainfall data from BMKG to represent climatic conditions (Silitonga et al., 2024). Non-spatial data were obtained from BPS, the Regional Disaster Management Agency (BPBD) of Demak Regency, and previous studies as supporting information. The details of the data collection instruments are presented in Table 1.

Table 1. Data Collection Instruments

No	Data Type	Data Format	Source/Institution
1	River Buffer	Map/Shapefile Layer	Geospatial Information Agency (BIG) or Public Works and Spatial Planning Agency (PUPR)
2	Rainfall	Statistical Data (mm/year)	BMKG
3	Soil Type	Soil Map	Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) or BIG
4	Land Use	Landsat Imagery/Map Layer	BIG or Ministry of Environment and Forestry (KLHK)
5	Slope	DEM-derived Data ,Slope (%)	United States Geological Survey (USGS) (SRTM/ASTER DEM)
6	Elevation	DEM Data (elevation, meters above sea level)	USGS or BIG
7	Data Population & Infrastructure Data	Population Statistics, Official Documents	Central Bureau of Statistics (BPS)
8	Flood Event Data	Annual Reports, Archived Documents	Regional Disaster Management Agency (BPBD) of Demak Regency
9	Literature & Previous Studies	Articles/Journals/Books	Academic Repositories
10	Primary Field Survey Data	Field Photographs	Researcher Data

Source: Processed Research Data, 2025

Data Analysis

Data analysis was conducted using two approaches: spatial and descriptive analysis. The spatial analysis employed Geographic Information Systems (GIS) to process six flood vulnerability parameters (river buffer, rainfall, soil type, slope, elevation, and land use) (Aulia Rahman, 2024). Each parameter was mapped, classified, and then overlaid using the Weighted Overlay method to produce a flood vulnerability map of Demak Regency (Yullia & Herawati, n.d.).

Descriptive analysis was used to explain the GIS mapping results, including the characteristics of each parameter and their relationship to flood potential (Irmawati et al., 2023; Rana et al., 2025). The resulting flood vulnerability map was compared with historical data from the Regional Disaster Management Agency (BPBD) of Demak Regency to assess the accuracy of the spatial model, strengthen research validity, and identify the dominant factors contributing to flooding (Segah et al., 2022).

RESULTS AND DISCUSSION

Use of Primary Data Based on Field Survey

Field surveys were conducted to obtain primary data on inundation and flooding conditions in Demak Regency, focusing on Sayung, Karangtengah, Karangawen, and Mranggen Sub-districts. Documentation results show that flooding occurs not only on main roads but also within residential neighborhood roads.

Figure 3. Waterlogging Conditions on Residential Roads
Source: Processed Research Data, 2025

Figure 3 shows waterlogging conditions on residential roads in Sriwulan Village, Sayung Sub-district, during heavy rainfall at night. The road experienced rainwater accumulation due to inadequate drainage systems, causing surface runoff to remain stagnant for an extended period (Wei et al., 2025). This condition reflects the vulnerability of residential areas, which are generally located on flat topography with limited infiltration capacity (Safiah Yusmah et al., 2020; Varma et al., 2025).

Figure 4. Waterlogging Conditions on the Semarang–Demak Highway
Source: Processed Research Data, 2025

Figure 4 illustrates flooding along the Semarang–Demak main road passing through Sayung Sub-district. The depth of inundation disrupted motor vehicle mobility, caused long traffic queues, and reduced community accessibility(Ramayanti et al., 2022)

Slope Gradient Parameter

Table 2. Slope Classification

No	Class	Description	Score	Weight	Area (Ha)	Percentage
1	0 – 8 %	Flat	9	0.20	94555.695	96.8 %
2	8 – 15 %	Undulating	7		759.549	0.8 %
3	15 – 25 %	Rolling	5		291.801	0.3 %
4	25 – 40 %	Hilly	3		2073.272	2.1 %
5	> 40 %	Steep	1		22.683	0%
		Total				100%

Source: Utomo (2004)

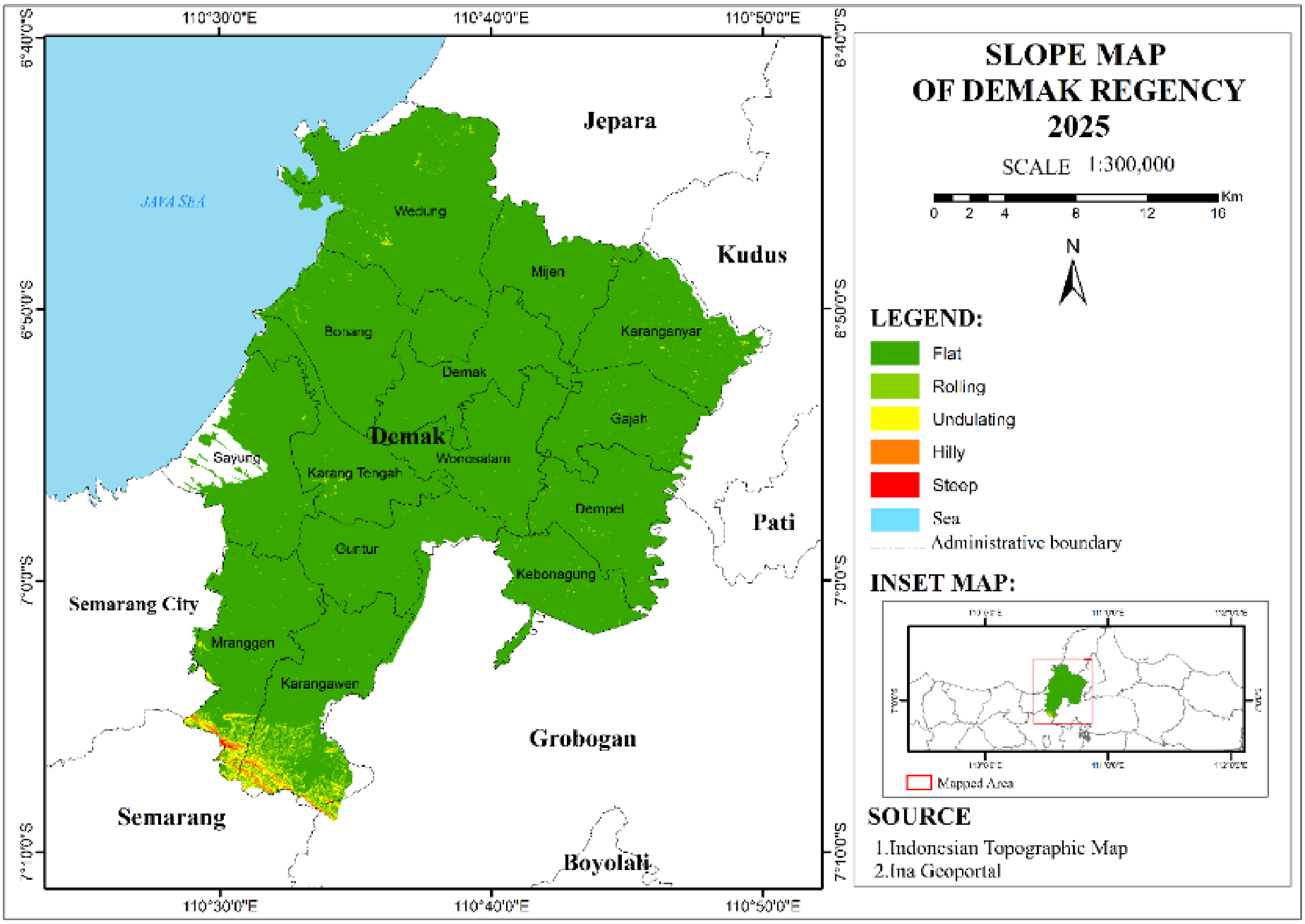

Figure 5. Slope Map
Source: Processed Research Data, 2025

Based on the 2025 slope analysis, the topographic condition of Demak Regency, as shown in Figure 5, is dominated by the flat class (0–8%) covering 94,555.695 hectares or about 96.8% of the total area (Table 2). This flat terrain is distributed almost evenly across all sub-districts, particularly in Sayung, Karangtengah, Bonang, Wedung, Demak, Wonosalam, and Kebonagung. The dominance of flat land has serious implications for hydrometeorological disaster vulnerability, especially flooding. This is because flat areas have very low surface runoff velocity, causing rainfall and upstream runoff to accumulate and remain stagnant for long periods.

Meanwhile, the undulating (8–15%), rolling (15–25%), and hilly (25–40%) classes, with a total area of about 3.2%, are only found in small parts of Mranggen, Guntur, and Karangawen Sub-districts. These areas are located in the southern part of Demak Regency bordering Semarang and Grobogan Regencies. Although these higher-elevation areas potentially function as water recharge zones and runoff sources, their very limited extent is not sufficient to offset the dominance of flat terrain(Handyastono et al., 2025).

Shrestha's study in Davidson County, Tennessee, used GIS and AHP methods to produce a flood vulnerability map. The results show that areas with low elevation and gentle slopes have higher flood susceptibility. This is consistent with conditions in Demak Regency, where flat topography and low infiltration capacity increase flood vulnerability (Shrestha et al., 2025).

Elevation Parameter

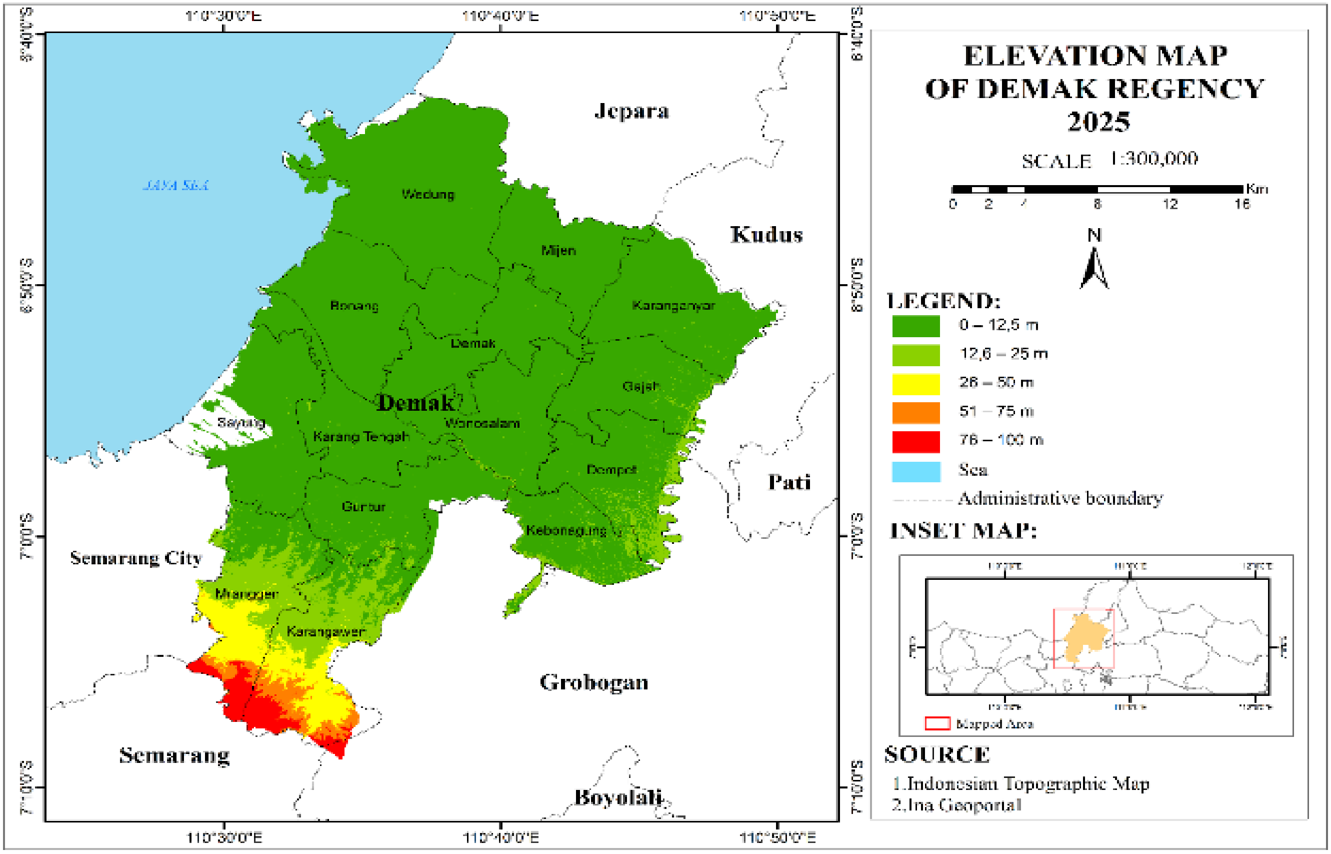

Figure 6. Elevation Map
Source: Processed Research Data, 2025

Table 3. Elevation Classification

No	Class	Description	Score	Weight	Area (Ha)	Percentage
1	0 – 12,5 m	Very Low	9	0.10	82908.356	84.9 %
2	12,6 – 25 m	Low	7		8083.247	8.3%
3	26 – 50 m	Moderate	5		3585.189	3.7 %
4	51 – 75 m	High	3		1441.613	1.5 %
5	76 – 100 m	Very High	1		1683.623	1.7%
	Total					100%

Source: Purnama (2008)

The elevation map indicates that Demak Regency is dominated by lowland areas (0–25 m), particularly in the northern to central parts, resulting from fluvial sedimentation processes from major rivers, which produce very gentle slopes. The southern region (26–100 m) consists of low hills and undulating terrain, functioning as rainfall catchment areas and sources of surface runoff. With 84.9% of the region classified as very low elevation, the highest flood potential occurs in the northern and coastal zones, due to rainfall accumulation, upstream runoff, and tidal flooding (rob). In contrast, southern areas are relatively safer, although still vulnerable during extreme rainfall events. Research Varra (2024), which shows that elevation significantly influences flood vulnerability using GIS-based AHP methods (Varra et al., 2024).

Rainfall Parameter

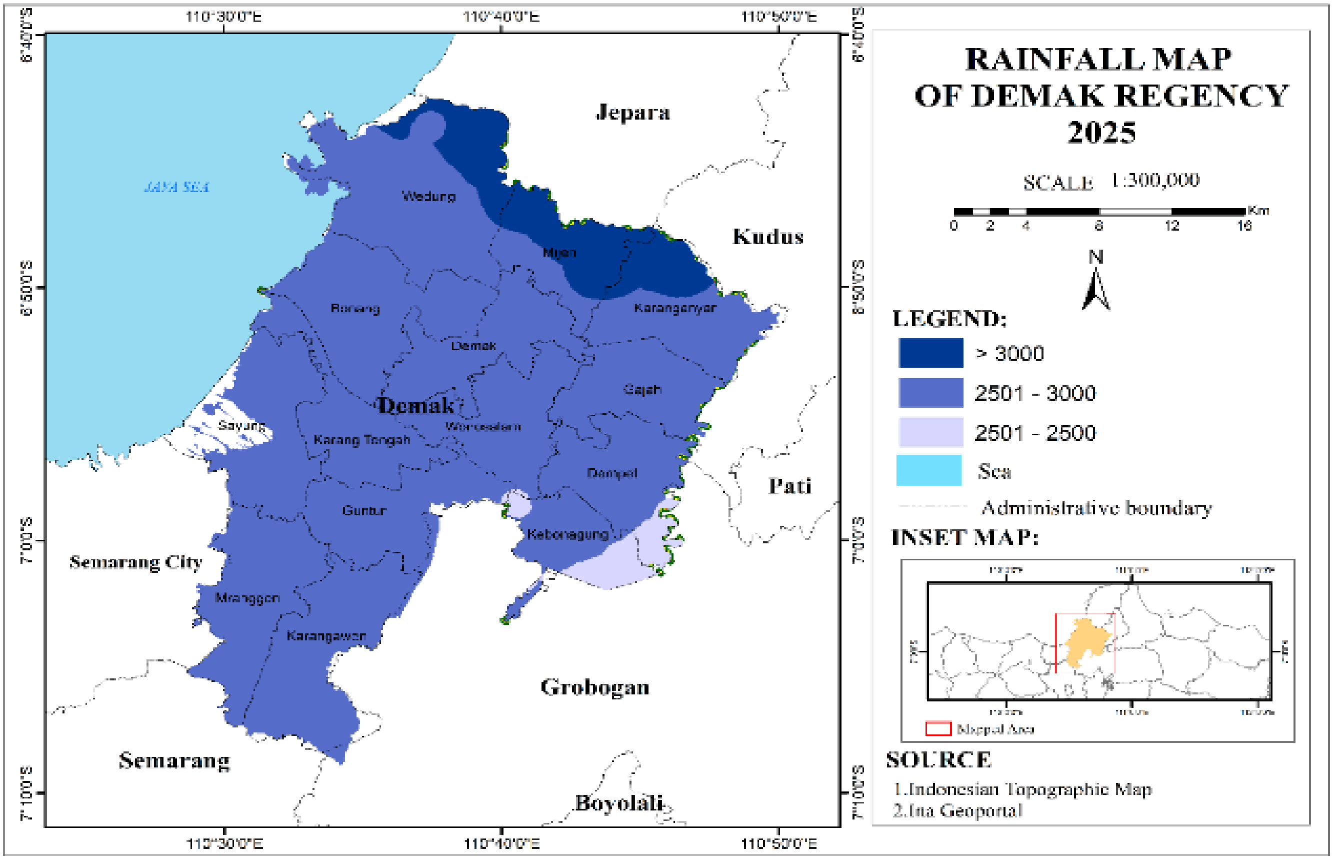

Figure 7. Rainfall Map
Source: Processed Research Data, 2025

Table 4. Rainfall Classification

No	Rainfall (mm/year)	Description	Score	Weight	Area (Ha)	Percentage
1	> 3000	Very Wet	9	0.20	8772.525	9.0 %
2	2501 – 3000	Wet	7		18123.394	18.5 %
3	2001 – 2500	Moderate/Humid	5		68321.438	69.9 %
4	1501 – 2000	Dry	3		2485.581	2.5 %
5	< 1500	Very Dry	1		0	0%
		Total				100%

Source: Primayuda (2006)

Based on the rainfall map (Figure 7), Demak Regency generally receives moderate to very high rainfall, with an increasing gradient from south to north. This pattern is influenced by lowland topography, monsoon wind direction, and proximity to the Java Sea. Table 4 shows that moderate/humid rainfall dominates (69.9%), followed by wet (18.5%) and very wet (9%) categories, while dry conditions account for only 2.5%. This condition, combined with low elevation (0–25 m), increases flood risk, including local inundation and upstream runoff, further exacerbated by limited drainage capacity, land-use changes, and watershed degradation. Climatologically, rainfall variability is also influenced by ENSO phenomena(Newson et al., 2022) .Penelitian Devi (2025) menunjukkan bahwa integrasi GIS dan penginderaan jauh efektif dalam memetakan risiko banjir, sejalan dengan temuan di shows that the integration of GIS and remote sensing is effective for flood risk mapping, consistent with findings in Demak that emphasize the influence of high rainfall and low topography on flood vulnerability (Devi et al., 2025).

Soil Type Parameter

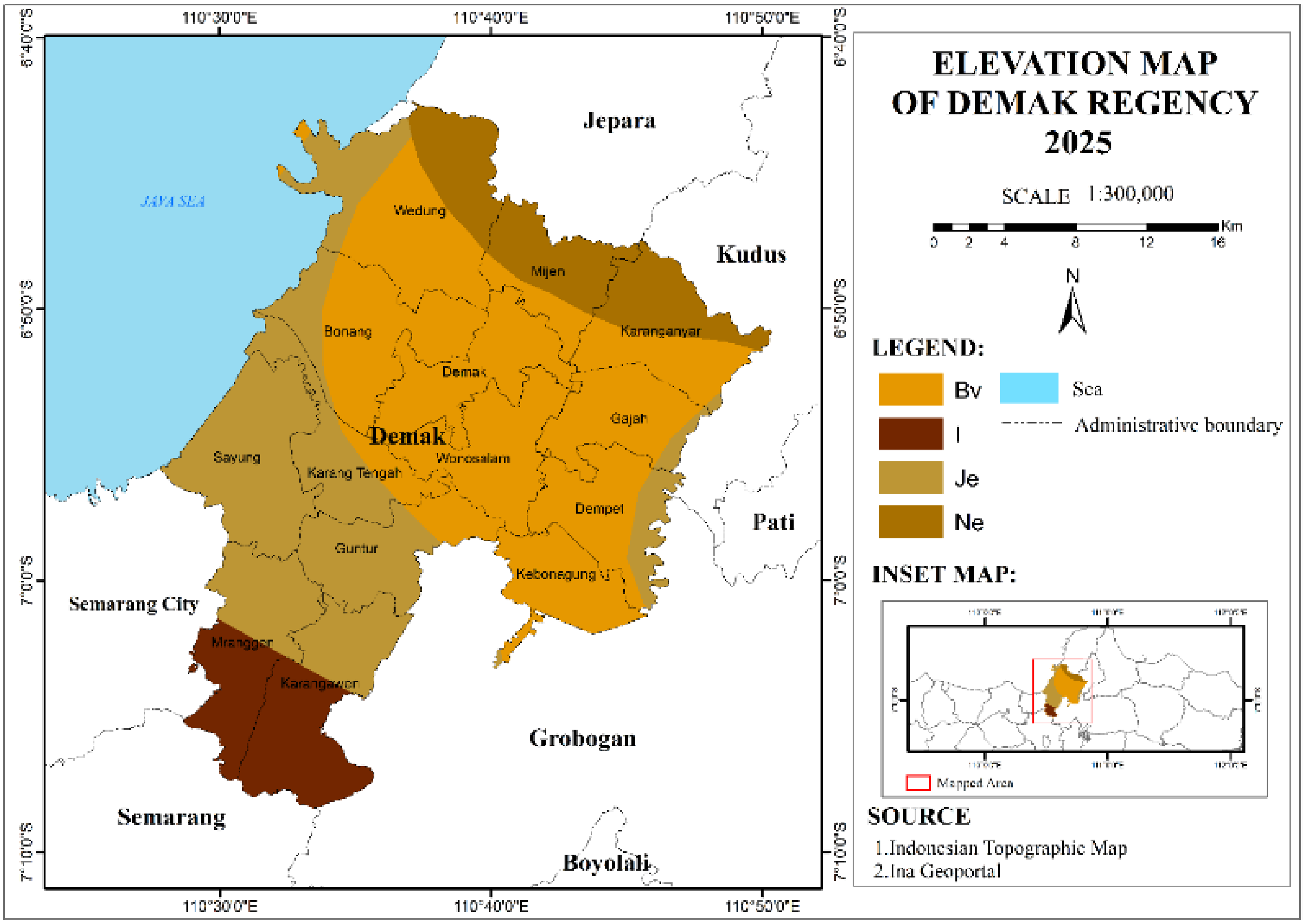

Figure 8. Soil Type Map
Source: Processed Research Data, 2025

Table 5. Soil Type Classification

No	Class	Description	Score	Weight	Area (Ha)	Percentage
1	Andosols, Mollisols	Low	1	0.10	48007.508	48 %
2	Vertisols, Ultisols	Moderate	3		9014.167	9 %
3	Inceptisols, Oxisols, Cambisol, Nitosol	High	5		31571.197	32 %
4	Vertisols, Entisols, Litosol, Flufusol,	Very High	7		11337.423	11 %
		Total				100%

Source: PUSLITANAK (2009)

Based on the Soil Type Map (Figure 8), the territory of Demak Regency exhibits a fairly diverse variation of soil types. The northern to central parts are dominated by Inceptisols and alluvial soil distribution, which generally have relatively high fertility levels but limited water infiltration capacity. Meanwhile, the southern part is more varied, with the presence of Andosols and Vertisol soils, which are commonly found in undulating to hilly areas.

In Table 5, it is shown that soils with low vulnerability levels (Andosols, Mollisols) dominate with an area of 48,007.508 ha or 48%. Soils with high vulnerability levels (Inceptisols, Oxisols, Cambisols, Nitosols) cover 31,571.197 ha or 32%, while the moderate class

(Vertisols, Ultisols) accounts for only 9%, and soils with very high vulnerability levels (Vertisols, Entisols, Litosols, Fluvisols) reach 11% of the total area. Although most of Demak Regency is classified as having low to moderate vulnerability soils, there are still quite extensive areas (around 43%) with high to very high vulnerability soil types.

The greatest flood potential is found in areas with Inceptisols and Entisols soils, which have relatively low water infiltration capacity. These soil types are generally characterized by relatively young profile development and limited infiltration capacity. As a result, during high-intensity rainfall events, most of the water cannot infiltrate the soil effectively and instead becomes surface runoff flowing to surrounding areas. This condition becomes more critical in lowland and coastal regions, where flat topography slows down water flow, causing inundation to persist longer(Shirzadi et al., 2025)

Research by Gebremichael (2025) shows that flood hazard mapping using a GIS-based approach that considers soil type, slope, and rainfall can effectively identify flood-prone areas. This study is consistent with findings in Demak Regency, where soil types with low permeability significantly contribute to flood vulnerability (Gebremichael et al., 2025).

River Buffer Parameter

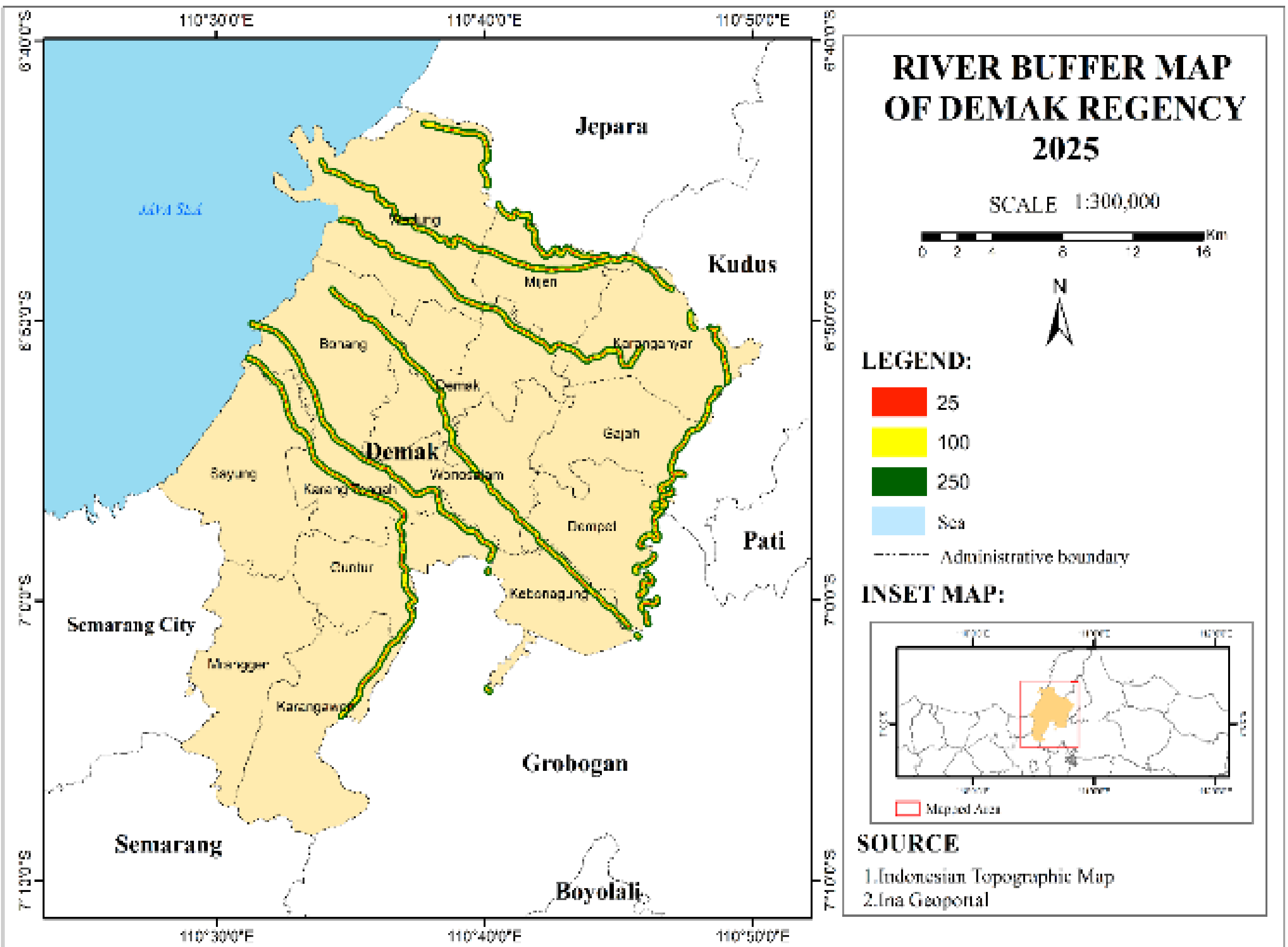

Figure 9. River Buffer Map
Source: Processed Research Data, 2025

Table 6. River Buffer Classification

No	Class	Score	Weight	Area (Ha)	Percentage
1	0 – 25 m	7		959.215	10 %
2	25 – 100 m	5	0.20	2907.724	30 %
3	100 – 250 m	3		5965.314	61 %
	Total				100%

Source: Primayuda (2006)

Based on the River Buffer Map (Figure 9), the area located in the closest zone to river flow (0–25 m) is relatively narrow, but has the highest level of flood vulnerability. This is supported by Table 6, which shows that the 0–25 m buffer area is only 959.215 ha (10%), yet it is highly prone to river overflow.

Several sub-districts included in this category are Karanganyar, Karangawen, Wonosalam, and Karangtengah Sub-districts, which are geographically traversed by major river flows. These conditions make these areas have a relatively high level of flood vulnerability because they are located along the main flow path that receives runoff from upstream areas. One of the sub-districts with the highest flood risk is Karanganyar Sub-district. This is because part of its area is located very close to the main river channel, making it potentially directly affected when river discharge increases due to high rainfall in upstream and local areas.

Research by Nguyen (2024) in Hanoi, Vietnam, also used GIS and AHP methods to map flood vulnerability. The results of the study show that factors such as distance from river networks significantly influence flood vulnerability. A similar condition is found in Demak Regency, where inadequate drainage systems worsen flood vulnerability (Nguyen et al., 2024).

Land Use Parameter

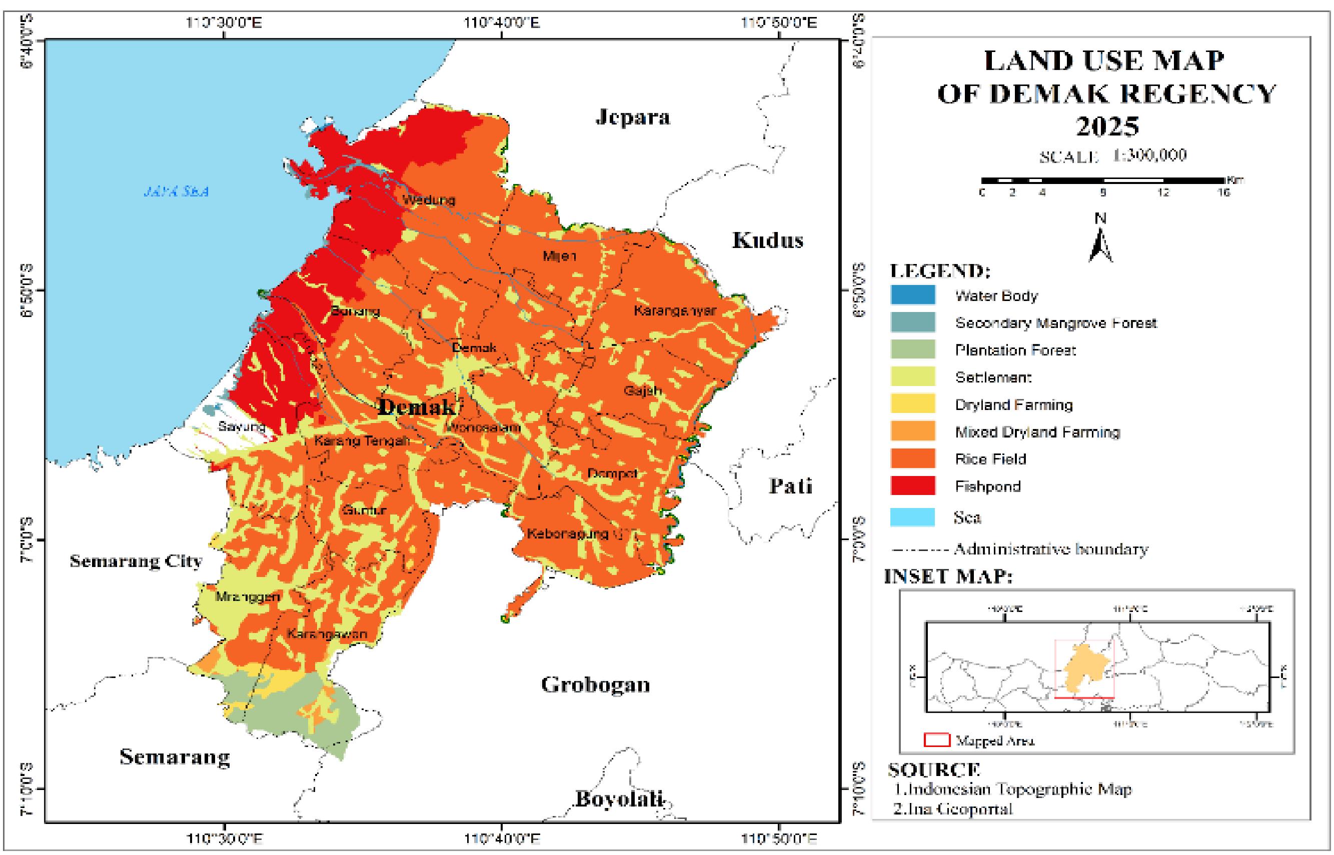

Figure 10. Land Use Map
Source: Processed Research Data, 2025

Table 7. Land Use Classification

No	Class	Score	Weight	Area (Ha)	Percentage
1	Badan Air	9		733.380	0.8 %
2	Tambak	9		11950.984	12.2 %
3	Sawah	8		62394.384	63.9 %
4	Hutan Mangrove	7	0.20	469.918	0.5 %
5	Permukiman	6		17830.635	18.2 %
6	Padang Rumput	5		973.977	1.0 %
7	Kebun Campuran	3		432.531	0.4 %
8	Hutan	1		2917.190	3.0 %
Total					100%

Source: Primayuda (2006)

Based on Figure 10 and Table 7, land use in Demak Regency in 2025 is dominated by rice fields (63.9%), settlements (18.2%), and ponds (12.2%), most of which are located in low-lying coastal areas. This condition increases flood potential because rice fields have limited infiltration capacity, settlements create impermeable surfaces that increase runoff, and ponds reduce natural infiltration areas while also being vulnerable to tidal flooding. Meanwhile, forests and mangroves, which function as water retention areas, only cover 3.5% of the region, making them insufficient to balance the dominance of built-up and agricultural land.

A study by Sugianto (2022) shows that land use change, such as the conversion of agricultural land into settlements, can reduce soil infiltration capacity and increase flood risk (Sugianto et al., 2022). In addition, research by Banjara (2024) reveals that rapid urbanization increases built-up areas, reduces natural infiltration zones, and exacerbates flood potential (Banjara et al., 2024)

Flood Hazard Map

Tabel 8. Luas Cakupan Kerawanan banjir

		Hazard Level and Area (Ha)			
No	Sub-district	Safe	Not Prone	Prone	Highly Prone
1	Bonang			850.862	7915.109
2	Demak			1226.205	5001.533
3	Dempet			1664.077	4622.826
4	Gajah			911.854	4418.585
5	Guntur			1367.691	4742.508
6	Karang Tengah			732.010	4886.102
7	Karanganyar			534.342	6478.069
8	Karangawen		1237.319	3860.948	3088.166
9	Kebonagung			2050.395	2449.999
10	Mijen			140.965	5222.433
11	Mranggen		521.392	4539.678	2351.401
12	Sayung			1880.422	4769.368
13	Wedung			269.944	12413.370
14	Wonosalam			1595.156	4786.468
Total		0	1890.603	22543.338	73269.059

Source: Research Data Processing Results, 2025

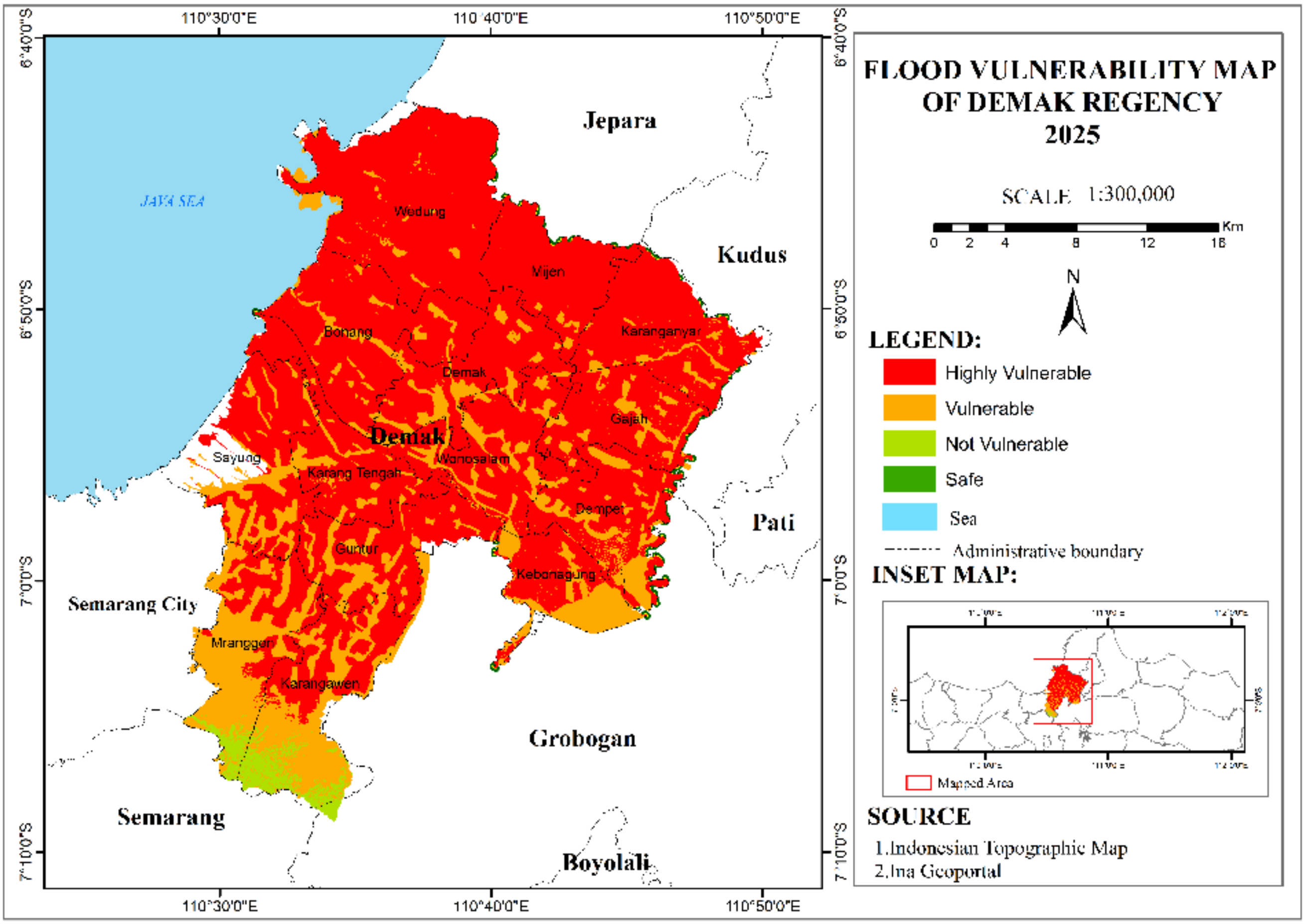

Figure 11. Flood Hazard Map of Demak Regency 2025
Source: Research Data Processing Results, 2025

The objective of this study is to analyze the level of flood vulnerability in Demak Regency using a multi-parameter spatial approach based on Geographic Information Systems (GIS). The analysis was conducted using six parameters, namely river buffer, rainfall, soil type, slope, elevation, and land use. The flood vulnerability mapping results (Figure 11) show that most areas of Demak Regency fall into the highly vulnerable category, covering 73,269.059 ha (74%), while the vulnerable category accounts for 22,543.338 ha (23%), and the not vulnerable category only 1,890.603 ha (2%) (Table 8).

High vulnerability is mainly concentrated in coastal areas such as Wedung, Sayung, Bonang, and Karanganyar Sub-districts. The dominant factors include proximity to major rivers and the northern coastline (river buffer parameter), high rainfall that accelerates runoff accumulation, and alluvial soil conditions with fine texture and low infiltration capacity. In addition, lowland topography with elevations <10 m above sea level (elevation parameter) and gentle slopes (slope parameter) further increase inundation risk. Land use in the form of ponds and rice fields (land use parameter) also significantly contributes to expanding flood-prone areas.

Southern areas such as Karangawen and Mranggen Sub-districts show zones classified as not prone, as they are located in higher elevation hilly areas with steeper slopes and relatively more permeable soil structures. These six parameters collectively explain the spatial variation of flood vulnerability in Demak Regency. This finding is consistent with international studies. Gul (2023) shows that the combination of flat topography, high rainfall, and agricultural coastal land use increases flood risk in river deltas in China (Gul et al., 2023).

Ground Checking through Satellite Imagery

Figure 12. Satellite Image of Wedung Sub-district
Source: Research Data Processing Results, 2025

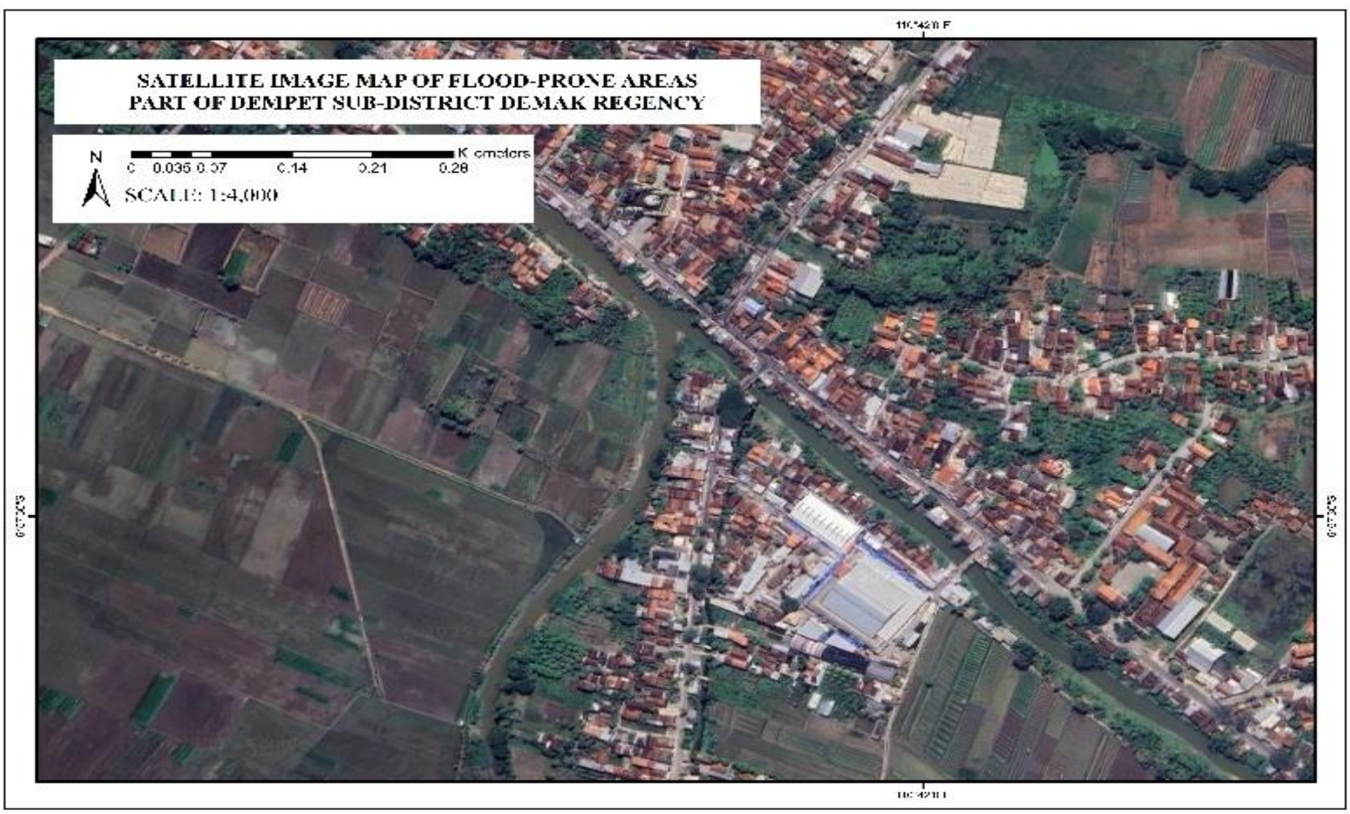

Figure 13. Satellite Image of Dempet Sub-district
Source: Research Data Processing Results, 2025

Ground checking using Google Earth Engine satellite imagery, with acquisition dated July 10, 2025, was conducted to verify the spatial distribution of flood vulnerability presented in the Demak Regency flood hazard map. Figure 12 shows the satellite image of areas classified as highly vulnerable in parts of Wedung Sub-district, Demak Regency. The imagery reveals land use patterns consisting of ponds, rice fields, and settlements distributed across coastal areas. The bright tones and linear patterns in rice fields and water channels reflect seasonal inundation patterns of high intensity. This is consistent with the very high vulnerability category, indicating that this area has a high potential for flooding, especially during the rainy season or high tide conditions.Findings by Tian (2022) support the claim that ponds and linear patterns of rice fields/water bodies in satellite imagery can be automatically detected, which is useful for quantifying pond and rice field areas that are vulnerable to inundation (Tian et al., 2022).

Figure 13 shows the satellite map of flood-prone areas in parts of Dempet Sub-district, Demak Regency. The imagery displays a mixture of dense settlements and rice fields, with several patterns of temporary water inundation. Inundation is observed in several rice field areas; however, its extent and intensity are lower compared to coastal regions. This appearance is consistent with the "prone" category, where flooding may occur but at a smaller and more uneven scale.

Research by Ashfaq (2025), which analyzed twelve hydro-geomorphological flood factors using Google Earth Engine (GEE), also shows that this platform is effective for mapping flood vulnerability in tropical regions (Ashfaq et al., 2025).Hal ini sejalan dengan temuan di Kabupaten Demak, di mana distribusi curah hujan yang tinggi dan topografi dataran rendah meningkatkan kerentan terhadap ban This aligns with findings in Demak Regency, where high rainfall distribution and lowland topography increase floodjir

Figure 14. Satellite Image of Karangawen Sub-district
Source: Research Data Processing Results, 2025

Figure 14 shows the satellite map of non-flood-prone areas in parts of Karangawen Sub-district, Demak Regency. The imagery indicates areas with dense permanent vegetation such as forests or shrubs, as well as scattered settlements. No significant indications of water inundation are observed in agricultural land or residential areas. This condition corresponds to the "not prone" category, indicating areas with relatively low flood risk and more stable drainage conditions..

Flood Vulnerability Validation through Community Perception

Flood vulnerability validation was also conducted by collecting direct information from local communities through interviews and focus group discussions across various sub-districts.

Figure 15. Participatory Interview with Local Residents
Source: Research Data Processing Results, 2025

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The results show that community perceptions and experiences are generally consistent with the flood vulnerability categories indicated by spatial maps and satellite imagery. In coastal areas such as Wedung, Sayung, Bonang, and Karanganyar, residents reported that tidal flooding (rob) and seasonal river overflow occur almost every year, with inundation lasting several days and causing damage to ponds and settlements, consistent with the "very high vulnerability" category.

In midland areas classified as "prone," such as Karangawen, Mranggen, Dempet, and Wonosalam, flooding is generally lighter and recedes more quickly, mainly affecting agricultural activities. In areas with dense vegetation classified as "not prone," residents reported that flooding rarely occurs; during heavy rainfall, water only flows briefly due to higher topography and more permeable soil conditions. No area was reported to be completely flood-free, as almost all sub-districts still have some level of flood exposure, even if minor.

Research by Savari (2025) in Iran shows that flood risk perception is influenced by social and environmental factors, such as topography and past experiences, which enhance community preparedness toward flooding (Savari et al., 2025). Meanwhile, Bullen (2024) demonstrates that participatory GIS approaches can bridge the gap between spatial data and community perception, enabling more accurate and locally relevant flood vulnerability identification (Bullen & Miles, 2024).

Recommendations

Based on flood vulnerability maps, ground checking, and community perceptions, mitigation efforts in Demak Regency should focus on improving drainage systems and river management in highly vulnerable coastal areas, normalizing drainage channels, and constructing embankments or polder systems to control runoff. Land use regulation is also important, considering the dominance of rice fields, settlements, and ponds that increase flood risk; adding vegetation or mangroves can help reduce water flow. In addition, the development of mitigation infrastructure such as retention ponds or reservoirs, as well as the strengthening of early warning systems and community education, will enhance preparedness

CONCLUSSION

This study shows that Demak Regency has a very high level of flood vulnerability, with the “highly vulnerable” category covering 73,269.059 ha (74%), the “vulnerable” category covering 22,543.338 ha (23%), and only 1,890.603 ha (2%) classified as not vulnerable. The dominant factors influencing flood vulnerability are the combination of physical conditions of the region, namely very flat slopes (96.8%), very low elevation (84.9%), and alluvial soil types (Inceptisols and Entisols) with limited infiltration capacity. In addition, moderate to very wet rainfall conditions (±97% of the area) and land use dominated by rice fields (63.9%), ponds (12.2%), and settlements (18.2%) further increase the risk of inundation.

The highest flood vulnerability is identified in coastal and lowland sub-districts, particularly Wedung, Sayung, Bonang, and Karanganyar, which are not only close to major river systems but also vulnerable to tidal flooding from the Java Sea. In contrast, southern areas such as Karangawen and Mranggen are relatively safer due to their undulating to hilly topography, higher elevation, and more permeable soil conditions.

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